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THE AUGUST SCIENTIFIC MONTHLY

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THE BOYCE THOMPSON INSTITUTE FOR PLANT RESEARCH. PROFESSOR JOHN M. COULTER 97

PARROTS AT HOME. DR. ALEXANDER WETMORE 107

HUNTING BIGHORN WITH A CAMERA. DR. VERNON KELLOGG 112

THE PROGRESS OF PUBLIC HEALTH IN CHINA. DR. REGINALD M. ATWATER 117

POLITICS AND THE PUBLIC HEALTH. JAMES A. TOBEY 123

EXCURSIONS IN EXPERIMENTAL PSYCHOLOGY. PROFESSOR RAYMOND DODGE 129

THE BIRTH OF MODERN SCIENCE. JOHN K. ROBERTSON 138

THE FRIENDSHIP OF TWO OLD-TIME NATURALISTS. J. S. WADE 152

GEOLOGIC ROMANCE OF THE FINGER LAKES. PROFESSOR HERMAN L. FAIRCHILD 161

RADIO TALKS ON SCIENCE:

The Planet Mars. JAMES STOKLEY 174

How Plants behave when Diseased. PROFESSOR B. M. DUGGAR 177

THE PECULIARITIES OF THE SENSATION OF COLD. PROFESSOR D. FRASER HARRIS 181

THE PROGRESS OF SCIENCE:

Electric Farming; A Queer Kettle; Professor Lucien Gallois; Variation of the Sun's Heat 184

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THE SCIENTIFIC MONTHLY

AUGUST, 1926

BOYCE THOMPSON INSTITUTE FOR PLANT RESEARCH

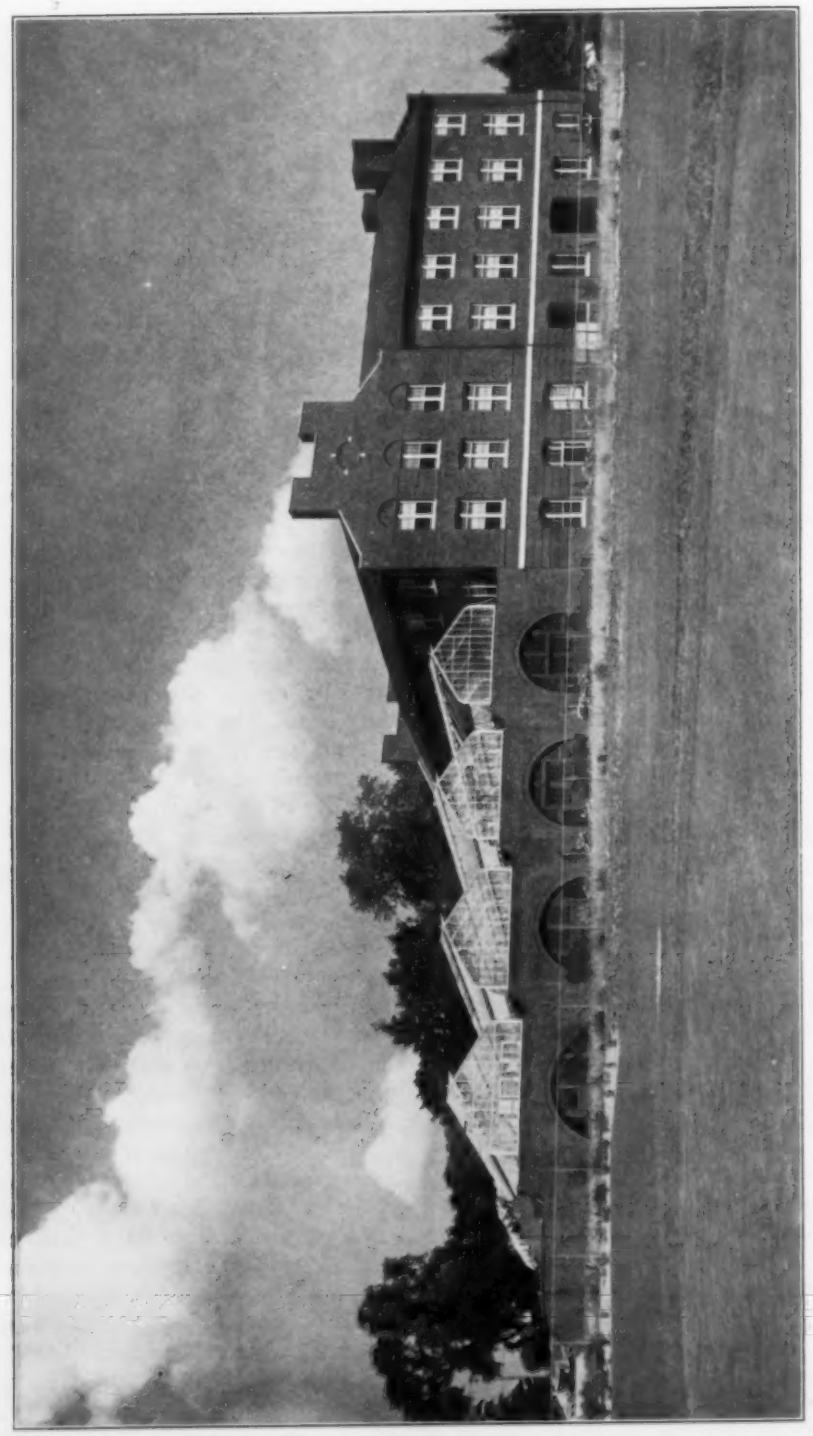
By Professor JOHN M. COULTER

BOYCE THOMPSON INSTITUTE

THOSE who are interested in the progress of science and of its service to human welfare should be informed of the work of the Boyce Thompson Institute for Plant Research, at Yonkers, New York. Colonel William Boyce Thompson had become impressed with the dependence of the whole population upon plants and their products. He felt that a great public service could be rendered if a more effective handling of plants could be secured. He realized that the problem was not merely to improve practice already in use, but through fundamental research to discover the possibilities of new practice. With this in view, the institute was planned and was officially opened for work in September, 1924, with sufficient endowment to provide the necessary equipment. It should be understood, however, that it is not a completed equipment, but an initial one. Further equipment will be secured as problems arise, so that the institute is a growing organization and not a static one.

The general aims of the institute at present may be summarized under three heads: (1) to secure the best possible equipment for the study of the entire life of plants; (2) to organize a cooperative staff representing every technique for attacking problems; (3) to attack the fundamentals of practical problems. In general, the botanical laboratories in America were poorly equipped for plant research. For example, they lacked good equipment for laboratories dealing with physics, chemistry, microchemistry, etc., as applied to plants. There was need also of special equipment for the study of plants during their entire life under controlled conditions. The equipment ordinarily available secured responses for only a short period, which did not apply to the whole life of the plant, and this resulted in many mistaken conclusions. The present equipment at the institute enables plants to be grown under controlled conditions, such as light of varying intensity, duration and quality, also varying temperature and moisture. In this way the whole series of responses of the plant throughout its life is secured, resulting in what may be called developmental physiology.

The staff includes investigators trained in all kinds of technique necessary for solving botanical problems. At present, physiology, pathology, biochemistry, physical chemistry, microchemistry and morphology are represented. In each of these fields of work there are varying phases of technique. For example, pathology includes bacteriologists, entomologists, protozoologists, etc. The same is true of the other depart-



BOYCE THOMPSON INSTITUTE FOR PLANT RESEARCH—EAST ELEVATION.

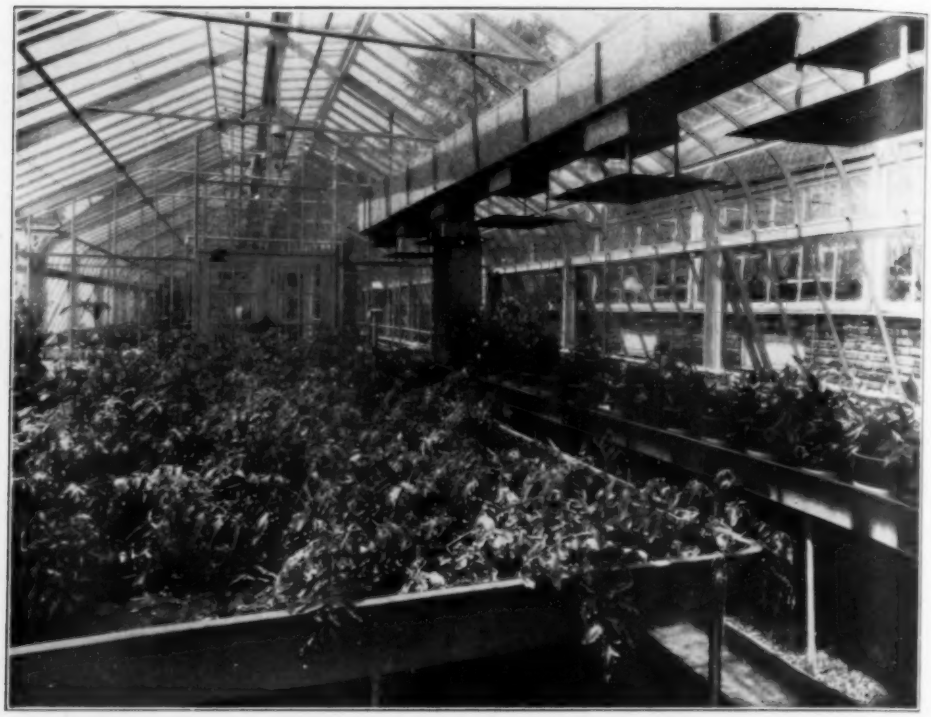
ments. All these phases are related to each other in the life of plants, and therefore the different investigators do not work separately, but in cooperation. It is recognized that plant life is a synthesis of all the sciences working together in producing the results. Probably the most important feature of the institute is the recognition that all phases of science must focus on a problem. One illustration of this cooperative attack may be taken from the investigation of the mosaic and yellow diseases of plants, in which the following lines of technique are being applied: pathology, entomology, protozoology, microchemistry, anatomy, biochemistry, physical chemistry and ultra-photography.

There are at present about thirty regular investigators at work, in addition to which there are thirty-three helpers to care for the many necessary details in connection with the investigations and the equipment. In addition to the permanent staff, a number of institutions, educational and commercial, are cooperating in supporting investigators to take advantage of the unusual equipment. In this way the institute is cooperating with other institutions in their investigation of fundamental problems.

A brief statement of the present equipment may be of interest, since it is probably the most complete and effective equipment at present for botanical investigation. The present building, which is only a section of the building planned, contains numerous laboratories, each with a very complete equipment for its purpose, but all of them coordinated in such a way that they can work together. In addition to the laboratories, there are sixteen greenhouses, providing for a wide range of control conditions. The controls already provided for include temperature, constant light and darkness, extra light, spectral illumination, humidity and carbon dioxide supply. A notable piece of equipment is that for supplementing daylight by artificial light at night. It is secured by means of an enormous gantry crane, which can be moved over the greenhouse at night and removed during the day. Its illuminating intensity is equivalent to that of daylight, so that the effect of daylight can be prolonged through any desired period. A few selections from the many problems being investigated at the institute will be made by way of illustration.

Propagation Studies

The institute is making extensive investigations of propagation from seeds and from cuttings, much of it in cooperation with nurserymen. It is found that seeds that need imbedding in soil preparatory to germination, called "stratification," depend chiefly upon the temperature of the soil bed. For example, the best temperature for many seeds is found to be about 5° C., but practice often fails through lack of proper control. The length of time necessary for stratification, to secure "after-ripening," is found to vary widely with different plants, even of the same genus. For example, in the rose genus, it is found that one species requires sixty to eighty days of stratification, while another species needs 120 to 140 days. In seeds that require short periods of stratification, sowing in the fall out-of-doors gives the desired result. In cases where a much longer period is needed for after-ripening, it seems probable that it can be secured by controlled cold storage, followed by a winter in properly treated beds, the seeds thus becoming ready for germination in early spring. The two things to be determined are the best temperature for after-ripening and the necessary length of time. Information in reference to these two factors is being supplied. For example, such information was asked by a nursery concerning



GREENHOUSE EQUIPPED FOR HUMIDITY CONTROL.

a certain dogwood, and the answer secured was that the best temperature is 33° F., and the time needed is four and a half to five months.

The investigation of propagation by means of cuttings is yielding important results. The factors studied are time of making the cutting, length of cutting, position of cutting and the effect of soil and chemical stimulants. It is found that plants propagated in this way vary widely in respect to these factors. What is good practice for some forms is ineffective for others. These propagation studies have proved of great interest to nurserymen and have suggested improvements in practice that are being adopted. The institute is being called upon to solve more commercial research problems than it can care for. As a consequence, its policy is to select from the numerous problems presented only those that promise progress in science and improvement in practice.

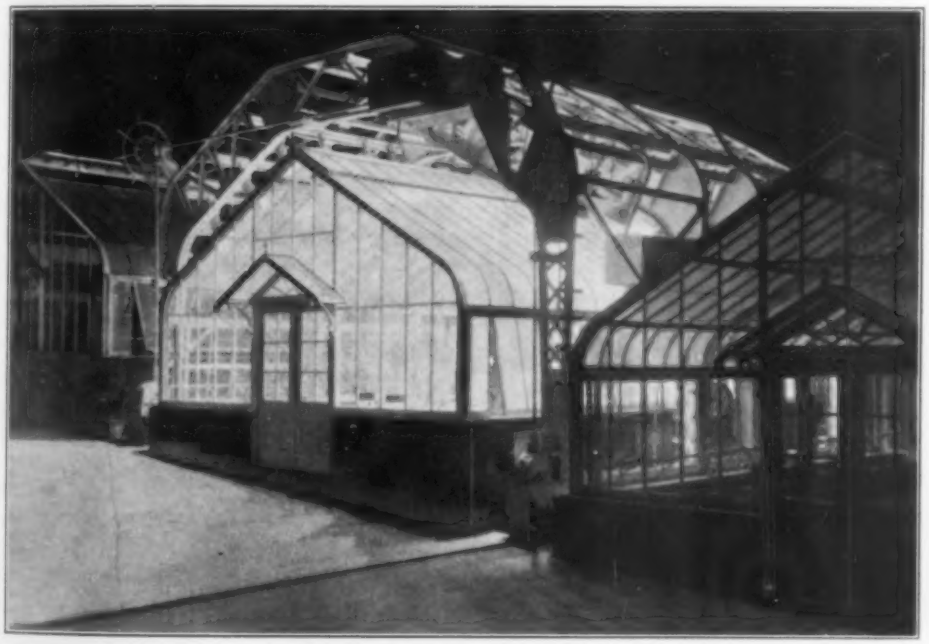
Chemical Regulation

The investigation of this problem has to do with the effect of chemicals upon awakening the plant from dormancy and securing immediate growth. The potato tuber was selected as the subject of experiment, not only because it is a notably dormant structure, but also because if it can be forced into speedy activity the result will prove of great practical importance. The problem was to discover the margin between the forcing action and killing action of the chemical. The extent of the experimental work may be realized from the fact that 224 different chemicals were tested, involving the use of about 3,000 separate experimental lots. The tubers were treated both cut and whole, and exposed to the chemical

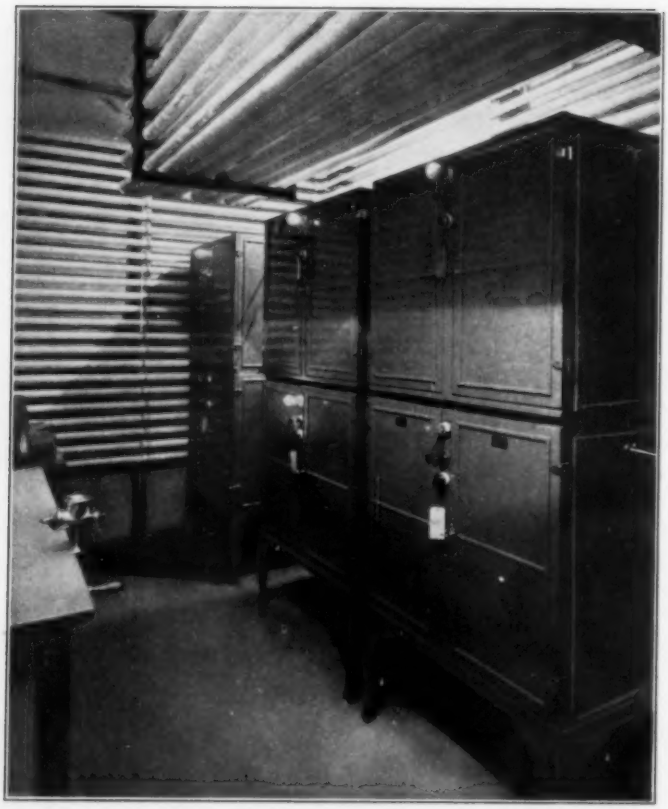
usually for one hour. By far the most promising chemical proved to be an ethylene compound (ethylene chlorhydrin), whose vapors were found to be remarkably effective in causing prompt germination. For example, in the experiments with a certain crop of potatoes, the treated lot produced vines two feet high, bearing tubers, before the untreated checks had appeared above the ground. The reason for this effect of the ethylene compound is evidently due to the fact that there is a very wide margin between forcing action and killing action. This forcing action in plant growth has opened up a very wide field in the handling of plants and proves to be not only of scientific value, but also promises to be of great practical importance. Work is proceeding to determine a standardized procedure in the use of ethylene chlorhydrin. It is certainly effective, but it remains to be discovered whether it can be put to practical use.

Certain other chemicals gave favorable results, but none seemed so effective as ethylene chlorhydrin. An interesting special case is presented by the chemical known as thiourea. In proper concentration it not only caused prompt sprouting of the potato, but also caused the development of more than one sprout from a single "eye," sometimes as many as eight. This means that in some way this chemical overcame the inhibiting effect of the main bud of the eye upon the subsidiary buds.

In this connection, attention may be called to the fact that the physiological chemistry of plants is far behind that of animals. This is probably due in part to the fact that such investigation is far more difficult in plants than in animals and also to the fact that the science of medicine has long been engaged in intensive work with animals. In animals the effect of what are called chemical regulatory agents is relatively easily studied,



GREENHOUSE ILLUMINATED AT NIGHT BY GANTRY CRANE.



REFRIGERATION ROOM WITH TEMPERATURE CONTROL CHAMBERS.

for animals have special glands for producing these substances, and an easy method of distributing them by the circulatory system. In plants there is no such specialized mechanism, and each cell must produce the regulative agents. This results in a very difficult problem for investigation.

Developmental Physiology

The investigations under this head are concerned with the effect of controlled conditions upon plant growth. The conditions under control are light, temperature, humidity and carbon dioxide. These controls are applied, associated with checks, throughout the whole history of the plant, from the seedling stage to maturity. Many plants have been subjected to these experiments, representing every combination of control, to discover the growth conditions. As might be expected, plants vary widely in their responses, and no result applies to plants in general. For example, it was found that the tomato and certain other plants suffer from daylight that lasts longer than seventeen hours. On the other hand, spring barley, petunia and some other plants were found to flower quickest and yield heaviest in continuous illumination, food manufacture proceeding uninterruptedly at the maximum rate. Investigation with other kinds of controls is also yielding important information.

Nutritional Physiology

This involves the chemical analysis of plants to discover what they are using

in the various tissues. Many of the methods in use are known to be inaccurate, sometimes accurate enough for certain plants, but not for others. The methods in use were investigated, to determine the limits of their usefulness and also to improve them if possible. As a result, some of them were found to be more reliable than others, and with the improvements suggested they can secure reliable results. For example, a method in use for the determination of reducing sugars was found to be accurate in its results under certain conditions. A method used for the estimate of total nitrogen in plant tissues was found to give too low results, but certain modifications promise to secure accuracy.

A special investigation was made of the tissues of apple trees and a method of analysis was worked out by which it is possible to secure accurate determinations of certain important compounds. At present there is no accurate method for the determination of starch in plant tissues, and therefore a promising investigation is in progress to secure an effective method.

A very interesting and important investigation in progress is the study of the seasonal changes in the apple tree. One hundred and fifty eleven-year old trees were secured for this study, and the seasonal changes in the chemical composition of the various tissues determined from the time of leaf fall in November to the period of fruit bud formation during the next season. The bark and wood of various years were analyzed at suitable intervals, to determine the chemical changes that were occurring. This is but a part of the general problem of the chemistry of fruit bud formation in the apple.

In addition to these major enterprises in nutritional physiology, there has also been cooperation with the investigations in certain diseases, as yellows and mosaic.

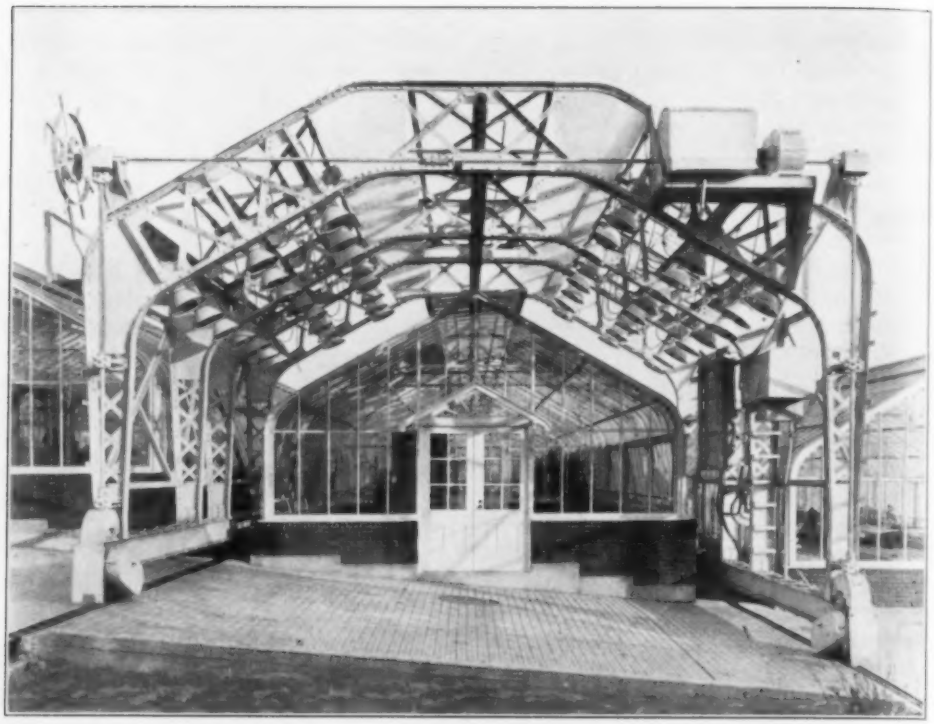
Another phase of work in nutritional physiology is concerned with the growth-producing value of the foods stored in various seeds and the effect of varying proportions of these organic foods in altering the shoot to root ratio. Seeds varying in the proportion of carbohydrates to nitrogen have been allowed to develop seedlings on their own nitrogen reserves in light, in darkness and in light in atmospheres containing carbon dioxide and lacking carbon dioxide, except for the small amounts given off in respiration. In all these conditions, the effect of additional nitrates was also studied. A great many interesting results have been obtained, showing wide variation in the behavior of different seedlings. For example, in the case of seedlings grown in darkness on their own nitrogen reserves, the total growth in grams of green material produced per gram of original dry food material ranged from 4.86 grams for low-protein corn to 32.51 grams for sunflower seed, a high-protein, high-oil seed.

A brief summarized statement will indicate some of the notable results thus far.

Seedlings from low-protein seeds, as corn, respond more to nitrates than to carbon dioxide or light. Seedlings from high-protein seeds respond to carbon dioxide and light more than they do to nitrates. Increased carbon dioxide and light have more effect upon the growth of roots than of shoots; while nitrates have more effect on the growth of shoots than of roots.

Plant Diseases

The investigation of plant diseases is another important field of work. This involves the discovery of the cause of a disease and then the development of some effective method of prevention. Many diseases are being investigated at the institute, but the most striking results have been obtained from the work upon mosaic and yellow diseases, and the latter will be used as an illustration. The yellow diseases have long been a



GANTRY CRANE FOR ILLUMINATING GREENHOUSES.

puzzle, and for many years their investigation has occupied the attention of plant pathologists. For example, peach yellows has destroyed many orchards, and yet it could never be discovered how the disease was carried from diseased to healthy trees. In attacking this difficult problem, the pathological division of the institute first studied aster yellows, a similar disease of asters, and succeeded in discovering the particular insect that carries the disease. This is only the first step in solving the problem, for it remains to be discovered what the insect carries that causes the infection. The carrier for aster yellows infects many other plants also, so that the infection may be carried over to quite a range of plants. The carrier for peach yellows, however, still remains to be discovered, but the pathologist is "on the trail." After the carrier and the thing carried are discovered, the final problem is to work out methods of effective control. Much work has also been done in connection with the diseases of decorative plants. This field has received comparatively little attention previously, because the chief attention of plant pathologists has been given to food-producing plants. The study of the diseases of decorative plants is being carried on in cooperation with nurserymen, florists and horticulturists, so that there is no lack of material and problems.

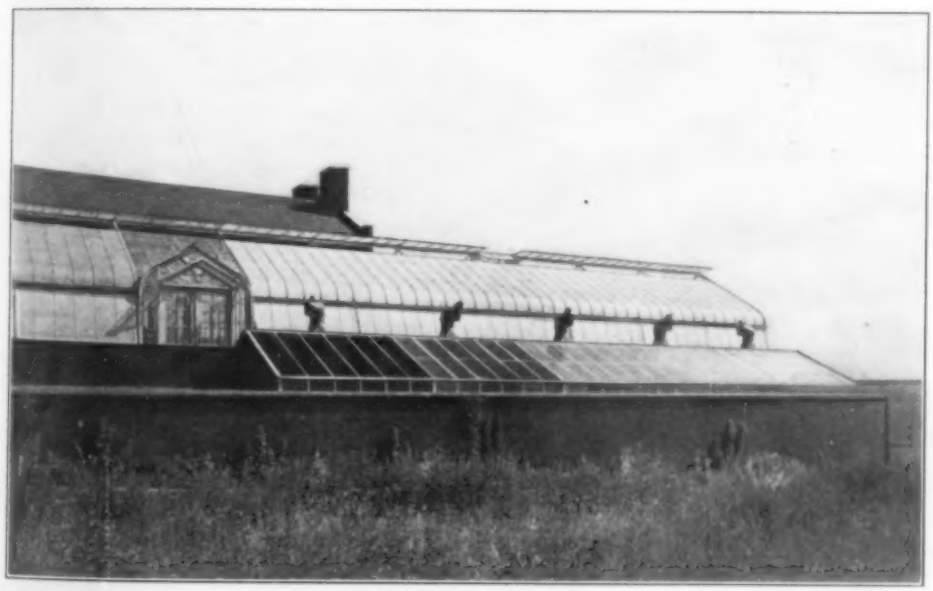
In connection with the study of diseases, much work is being done to develop effective fungicides and insecticides. A sulphur compound has been secured which has proved to be most effective in controlling such pests as codling moth, leaf roller, apple scab, etc. The process for securing it has been improved so that it can be manufactured

in large quantities and thus be made available for extensive use.

It is recognized that the destruction of the infecting organisms is not the final stage in the control of plant diseases, but rather a temporary stage until disease-resistant races of our plants are developed. To prevent the spread of disease by the destruction of infecting organisms is a temporary goal, but to secure immune races of our important plants is the final goal.

Much work has also been done in secured seed sterilizers that will insure seeds against infection which has often resulted in the failure of crops. The problem is to secure a sterilizer that will kill fungi and bacteria, without injuring the seed or plant.

The foregoing very general statement may leave the impression that the institute is more concerned with practical problems than with fundamental investigation. Such an impression should be corrected. The two organizations heretofore engaged in plant research have been the United States Department of Agriculture and the universities. Investigators in the Department of Agriculture frequently state that they are not permitted to go far enough into the fundamentals of the problems they are dealing with. Congress is always demanding immediate practical results, and to meet this demand the fundamentals too often have to be neglected. The same is true of state universities, for the state legislatures are always emphasizing the need of practical results from their appropriations. The Boyce Thompson Institute is dealing with both the fundamentals and the practical and is trying to meet both the scientific need and the public demand. Of course many of the fundamental investigations being carried on do not promise to be of value in practical application, but result in increasing knowledge of the laws of plant develop-



SPECTRAL-GLASS GREENHOUSES.

ment. To understand the plant is the main purpose, and to use some of our knowledge in the handling of plants is merely a corollary. The atmosphere of investigation at the institute does not feel the continual urge of application. It is realized that the more fundamental the investigation, the wider may be its possible application. Practice is merely the superficial application of some of our knowledge. There can be no conflict between fundamental investigation and practical application. In fact, they are of mutual service in the progress of knowledge. Botany is especially well adapted to develop this joint attack upon its problems.

It should be realized that the institute is continually urging caution as to the practical value of its results. Results secured in a laboratory may not prove practical on a large production scale. The program, therefore, is first to conduct investigation in the laboratory under controlled conditions; then to try out the promising results on a small field basis; and, finally, if successful thus far, to extend the application to the large production basis.

PARROTS AT HOME[1]

By ALEXANDER WETMORE
ASSISTANT SECRETARY, SMITHSONIAN INSTITUTION

PARROTS are displayed in zoos in such number and variety that as a group they are probably better known in captivity than any other order of birds, with the possible exception of pigeons. Many persons keep captive parrots as pets at home, and a zoo without parrots would be a curious place indeed. The popularity of these birds is due to the ability of some kinds to imitate human speech, and also to their great length of life as compared with that of most other captive forms. It is not unusual for parrots to live in health for twenty or thirty years, and there is in the National Zoological Park a beautiful sulphur-crested cockatoo that was brought to the park when it was first established in 1890. It was then a mature bird of unknown age, and is to-day in perfect health after thirty-five years as a friend of the public. It is the oldest animal in the collection. Such birds have been known to reach an age of eighty years.

Though savage tribes living in the warmer parts of the earth almost universally keep living parrots as pets, these birds did not become well known in Europe until the time of the Roman conquests. They were common in Rome during the period of the Roman Empire but then practically disappeared until the voyages of exploration began in the fifteenth century of the present era. Since the opening of the nineteenth century parrots have become widely known, and for many years have been imported into this country in large numbers.

[1] One of the series of Radio Nature Talks from the National Zoological Park, arranged by Mr. Austin H. Clark; broadcasted from Station WRC, Washington, December 26, 1925. The illustrations are by courtesy of the National Zoological Park.

In the entire world there are nearly six hundred different kinds of parrots, which are usually divided into two groups, the parrots and cockatoos proper, and the lories. As a group parrots are easily recognized by their heavy bodies, short necks, round heads, small eyes and strong, heavily hooked bills. Their bodies are covered with firm feathers that are usually bright in color. Green is the most common shade in their plumage, often variegated with red, yellow, orange, blue or black. Many are gorgeously marked.

In spite of their bright coloration parrots are often difficult to see. I recall very well, while in a jungle swamp in eastern Porto Rico, a flock of a dozen parrots that swept into a tree twenty yards away, saw me and immediately became motionless so that they seemed utterly to disappear. After ten minutes of careful watching I was able to make out the outline of the head of one bird, but of its colors I could distinguish nothing amid the green of the foliage. Frequently in other parts of the world I have had flocks of parrots fly into a tree above me and then fly away before I was able to distinguish a single individual.

The legs of parrots are short and the feet, like those of a woodpecker, have two toes directed forward and two behind. The upper part of the bill is attached to the skull by a hinged joint that allows free movement up and down, and frequently has a rough surface like that of a file on the inside at the tip, that assists in holding seeds so that they may be cracked and the kernel extracted.

The tongue in ordinary parrots has a soft cushion at the tip, controlled by muscles so arranged that it is freely

THE BLUE AND YELLOW MACAW.

THE GREAT RED-CRESTED COCKATOO.

flexible and serves as a finger to assist in holding and extracting food. The lories have the edge of the tongue fringed with fine filaments so that it resembles a brush. With this they extract nectar from flowers or eat soft juicy fruits.

It is a wide-spread superstition that to enable a parrot to "talk" (in imitation of human speech) it is necessary to split the tongue. This, however, has no foundation in fact, and when practiced only inflicts an unnecessary cruelty. Birds make sounds in a little organ known as the syrinx at the lower end of the trachea or windpipe, and as the tongue has little to do with the process, splitting it has no connection whatever with the ability to imitate sounds.

The calls of parrots living in freedom are as harsh as those that greet our ears in the bird house at the zoo, but are not so disagreeable, since they are usually softened by distance. When feeding parrots are quiet but in flight the larger kinds are very noisy and the approach of flying flocks is heralded long in advance by their strident cries. The smaller species are much afraid of hawks and if feeding in the open fly out with great clamor at any alarm. In the Chaco of South America I found the monk parrakeet in great flocks that fed on the ground in old fields of mandioca and sweet potato and at the passing shadow of every buzzard rose to circle with shrill cries. These birds were much afraid of storms, and when lightning flashed, even below the horizon, the parrakeets were restless and uneasy.

Most parrots lay their white eggs in cavities in trees, where their young are free from danger, but a few vary from

this habit. In southern South America the monk parrakeet joins in bands that build in company a structure of sticks that forms a veritable apartment house in which each pair of birds lives in a separate cavity. These communal nests are used year after year and often grow steadily in bulk. I have seen several that were six or eight feet in diameter and contained enough sticks and twigs to fill a wagon. In early days in the Pampas these birds nested in the low trees that formed occasional groves on the plains. Man introduced eucalyptus trees which grow to a great height, and now the monk parrakeets build nests in the branches of these trees often sixty or eighty feet from the ground. A species of duck known as the tree teal, somewhat similar to our green-winged teal, preempts a chamber in this same communal structure, lines it with soft down, and hatches its own young amid the noisy chatter of its companions. I never became wholly accustomed to the strange sight of these little ducks standing on one leg asleep on some dead tree limb fifty feet from the earth in the vicinity of their nests. When hatched the young ducklings are supposed to tumble out and fall to the ground, where they alight without injury because of their slight weight. I have seen a mother duck on the ground leading her young to water, but was never fortunate enough to observe them leaving the nest.

Parrots are distinctly creatures of habit and follow a regular routine of daily life. The smaller kinds often resort to holes in trees to roost or for that purpose gather amid dense protecting branches. When sleeping some species hang in close bunches by the bill or feet, while others perch on branches like other birds. Parrots do not leave their roost until the sun has warmed the air and dispelled the damp morning chill that is felt even in the tropics, and then in flocks or in pairs they fly out in search of food. Late in the forenoon they fly to water to drink and then feed or rest for the remainder of the day. Their habit of flying to some drinking place is so well known that on one occasion in an arid desert section in Mendoza, Argentina, I followed the flight of a flock of parrakeets for nearly two miles to an alkaline pool where I was able to quench my own thirst.

Although the parrots as a group are so remarkable for the regularity of their daily routine, it is among them that we find one of the most extraordinary cases of the adoption of a new habit known anywhere in the animal kingdom. Those who are familiar with the zoo in Washington may recall an outdoor cage near the bird house in which are several large dull-colored parrots. These are the keas, which come from the hills of New Zealand. The keas are often quiet during the day, but toward dusk or in stormy weather, especially during the colder season, they become very active. At such times their shrill, drawn-out cry, which resembles the syllables of their name, resounds throughout that part of the park. They are playful and mischievous and delight in cutting up logs of soft decaying wood, or in plugging with sticks the drain in their cement water pool.

In their native home in South Island, New Zealand, they are found in the mountains, descending to lower elevations in the winter. With the coming of the white man keas came to feed upon scraps of meat thrown out about camps and houses, or to pull bits of fat or flesh from sheep skins hung out in the air to dry. From this they learned to attack living sheep. Several will alight on the back of a sheep and with their long sharp bills tear apart the wool and skin to reach the delicious fat over the kidneys. This, of course, kills the sheep. Occasionally the birds even attack horses. It has been reported that as many as two hundred sheep have been killed from one flock in the course of a single night

and in some districts the keas finally became so destructive that sheep could not be raised where these parrots were common. Settlers placed a price on the heads of the birds and so reduced their numbers. In 1922 keas were reported as still plentiful in the upland regions. It is from this section that the birds exhibited have come.

Though parrots are commonly considered tropical birds, a few kinds range into colder regions. The barranca parrot of Argentina, which nests in a hole dug in the face of some cut bank above a stream or dry arroyo, is found throughout Patagonia to the Straits of Magellan, where snow and sleet may come in any month of the year, and summer is far from the season of warm weather that we experience in more temperate areas. Another species of parrot is found in forests in the same region. Parrots and penguins seem opposites in range yet it is possible to see the two in close proximity along the shores of the ocean channels of southern Patagonia. In the Macquarrie Islands, beyond Australia, in Latitude 55° South, there is also a parrot, which lives amid such bleak, inhospitable surroundings that we may well wonder how the bird became originally established there.

In North America, too, there are parrots that do not fear the cold. In the early history of our own country the Carolina paroquet, a small parrot about twelve and one half inches in length, with orange and yellow markings on the head and neck and the rest of the plumage bright green, was found throughout most of the eastern United States north to Maryland, the Great Lakes Region and Nebraska, where it ranged in flocks that at times wandered even farther north. Originally these birds lived on the seeds and fruits of various trees, thistles and cockle-burs. With increased settlement they came to fruit orchards and fields where their destructiveness, coupled with their bright colors and noisy habits, led to their extermination by shooting over wide areas. It is supposed that a few persist still in the depths of cypress swamps in parts of Florida, as every year they are reported there by deer and turkey hunters. None has been found by naturalists since 1906 so that they are now very rare. In 1917, on the Gulf Coast of Texas, I was told of some bright green birds with yellow and orange in the plumage that had come to feed on China berries at a ranch near the mouth of the Brazos River. It is possible that the paroquet still exists in the swamps of that region.

In this connection I may note that recently I have identified an extinct cousin of the Carolina paroquet in a fossil state from northwestern Nebraska from bones that are supposed to be two million years old.

In northern Mexico there is a larger parrot with a long tail known as the thick-billed parrot that feeds on the cones of pines and on acorns. At irregular intervals this bird comes north across our border into the Chiricahua, Huachuca and Graham Mountains, and other nearby ranges, in southern Arizona, where it may remain in flocks for a year or more before it disappears. On occasion some have been captured alive, and we have had them in former years displayed in the bird-house at the zoo. In its native home in Mexico the thick-billed parrot ranges in forests of pines and oaks in the same areas as the imperial woodpecker, a wonderful bird as large as a crow. These two species have a curious relation to one another, as the parrot uses the old nesting holes of the woodpecker, cut in the trunks of trees, as a home for its own family where it may rear its young in snug protection from the elements.

In connection with the thick-billed parrot it may be noted that they have been long known in captivity. Mr. Neil

M. Judd, of the National Museum, who for five years has had charge of the work of excavation of the ancient Indian village site at Pueblo Bonito, New Mexico, has found there bones of many birds. Among these I have identified bones of the thick-billed parrot, together with the military macaw, the red, blue and yellow macaw, and the white-fronted parrot of Mexico. We suppose that these birds were brought from the south through channels of trade and barter among the Indians.

Many Indians eat the flesh of parrots regularly and when in camp where meat was scarce I have on various occasions eaten them myself and have found them as palatable as pigeons. Cooked with rice, their bodies formed the basis of many a dinner. They were considered a great table delicacy in the days of the Roman Empire, and it is said that one Roman Emperor imported parrots to feed to his captive lions.

Though similar in general appearance parrots vary greatly in size, from little love-birds, smaller than a sparrow, to giant macaws three feet long with huge bills as large as tea-cups. Their habits vary as widely. Much time might be consumed in relating strange traits, but with this brief review I must conclude my account.

HUNTING BIGHORN WITH A CAMERA

By DR. VERNON KELLOGG

NATIONAL RESEARCH COUNCIL

THE Rocky Mountain sheep, or bighorn, is one of the most extraordinary and interesting of American animals. It is not limited to the Rocky Mountains, but varieties of it are found also in the Sierra Nevada and in the mountains of Alaska and Mexico. In earlier years it was a great favorite of big-game hunters but is now protected by game laws.

As a boy interested in natural history I had read all that I could find written about the bighorn. Especially had I soaked up all the stories about its wonderful surefootedness, its marvelous speed over rough rocks, and, most thrilling of all, its alleged habit, when closely pressed, of leaping headfirst over high sheer precipices and landing on its great strong curved horns. Of course, only the males, and the old males at that, have the big horns, so that the ewes and young would not be able to follow the head of the family in this wild leap for liberty. Rather selfish of father, it would seem, to desert the family this way. But he had this good excuse. The hunter was really after father and that pair of big horns for a trophy, and was likely to let mother and the kids alone—unless, unfortunately, he was hunting for meat and not glory.

When I got to college and began to study natural history seriously I still remembered the stories about the bighorn, and kept an eye out for a chance to get to Colorado and into the Rockies to see these interesting animals in their rocky fastnesses far up among the great peaks. Also, as I lived in Kansas, which, whatever else it has in the way of scenery—and that isn't much—has no mountains at all, I wanted to see mountains, high mountains and deep canyons, with great silent forests of spruce and pine and swift clear mountain streams with trout in them. I wanted to camp and climb and see bear and elk and deer—and bighorn.

So five or six of us college mates figured out very carefully what it would cost to spend a summer in the Colorado Rockies. We had to figure carefully, for we were all poor, and our families thought they were doing enough to support us in college without grub-staking us for an expedition after bear and bighorn in Colorado. We decided that we could live chiefly on flapjacks, trout, bear-meat and wild red raspberries, of which menu only the flapjacks would cost us anything. The rest of the food we would find in the mountains. We would do our traveling on foot, after once getting to Colorado, with perhaps a burro or two to help carry our packs. In addition to our guns and trout rods we would take cameras, and I, at least, registered a solemn vow that I should hunt bighorn, if not with a gun, which was prohibited by law, at any rate with a camera. And I may say right now, based on considerable experience, that hunting wild animals with a camera is no less exciting than hunting them with a rifle, and requires not less, but more, skill and persistence.

Our little group of Kansas college freshmen was composed of chaps who had some stuff in them. There was Fred Funston, who later fought in the Philippines, captured Aguinaldo and became a major-general in the U. S. Army; Her-

bert Hadley, who became governor of Missouri, and only narrowly missed being nominated for president by the Progressive Republican party in the days of Roosevelt; William Allen White, now a well-known editor, author and publicist; and two brothers, named Franklin, one of whom has become an eminent chemist and the other as eminent a mathematician and physicist. But at the time of our trip after bighorn we were all as green as Kansas corn in a good summer, and perfect tenderfeet as far as camping, climbing mountains and hunting big game were concerned.

But I must get along to the bighorn. We made headquarters camp in a beautiful little, high-level, glacial valley in the Front Range of the Colorado Rockies, and started our climbing by getting to the top of Long's Peak, 14,255 feet in altitude, and one of the highest, most difficult and dangerous of the Colorado peaks. After that we did all the other peaks in the vicinity. It was great sport—and always with the tang in it of a little danger. Funston and I once got caught in a violent snowstorm on top of an especially rough peak. The snow changed to sleet while we were out in the middle of a great snowfield which lay at a steep angle on the mountain flank and simply had to be crossed in order to get down to timberline from the summit. The surface of the field became like ice, and we could only move over it by breaking through the crust for each footstep. It was very dangerous going, for once started on a slide we couldn't possibly have stopped until we got to the bottom of the field, which was at least a thousand feet below, and margined by a rampart of rock against which we would have dashed at terrific speed. But we made a special point of not slipping—and didn't!

After we had cleaned up all the nearby mountains, in the course of which we saw many signs of bighorn—especially their many narrow little trails cut three or four inches deep along the mountain flanks well above timberline, but none of the animals themselves—we learned from an old hunter and trapper, who lived alone in a rough cabin not far from our camp, that while the wild sheep used to be plentiful in the near-by mountains and still were to be found there occasionally, more of them could be found in the high mountain country farther north toward the Wyoming line. So we packed up Billy the Burro to the limit of his capacity to carry things, put the rest of the camping outfit on our own backs and started north. We picked up trails when we could find any, but mostly we just headed north. For much of our way we worked along the flank of the range above timberline, to which we had to come down at night to make our campfire for cooking and keeping warm. We had been told of a long extinct volcanic crater called Specimen Mountain to which the bighorn were reputed to come from long distances away in order to lick on the green and yellow beds in the crater bottom. This was our goal.

On our way we started up a rather small bear and chased it into a hole in a great rock pile. How to get it out? After sitting around the hole for a while, without working out a satisfactory way, Funston finally suggested this interesting plan. He volunteered to crawl into the hole and stir up the bear, which would presumably get angry and chase him out. The rest of us were to stand by the side of the hole and shoot at the *second* object to come out; the first one Funston fondly expected would be himself. This plan seemed reasonable, but on careful consideration we vetoed it; there seemed to be just a chance that nothing at all might come out of the hole, not even the future capturer of Aguinaldo himself.

Finally we arrived near Specimen Mountain and established camp in a beautiful high level pass only a little below timberline. This pass was really part of the Continental Divide, for the water which flowed down from one side of it was carried into the North Platte, thence into the Missouri, the Mississippi and finally into the Gulf of Mexico, while the water from the other side, only a hundred yards away, flowed into the Grand River and thence by the Colorado River into the Gulf of Lower California. There was plenty of water and firewood, and by scrambling down a thousand feet to the Grand we could get all the trout we could eat. It was a fine camp. We were now ready for bighorn.

Excitement soon came, although at first not from bighorn. One of the boys had left camp with a shotgun soon after we had got things in order, a cooking place fixed up with stones, level places found on which to spread out our bed blankets, and our flapjack flour, sugar and salt under cover of a rubber poncho. The hunter had gone forth to try to find a blue grouse or two for supper. His shotgun shells were loaded with large birdshot. Just at dusk he came back madly running and calling for help.

It seemed that in his wandering he had discovered a little bear cub, and, like the proper tenderfoot that he was, had sent a load of birdshot at it. The cub was not much hurt, but enough to stimulate it to a loud squealing which had brought an angry mother bear to the rescue. There was nothing for the brave hunter to do but to start for camp with all possible speed, which he did, without hesitation and with no glances backward. One sight of mother bear had been enough. It was, according to the hunter, probably the largest grizzly bear that had ever existed in the Colorado Rockies! Fortunately for our indiscreet hunter—and for us—mother bear did not follow him to camp, but turned back to her cub.

And now came the bighorn. Literally that. For as we busied ourselves with cooking supper, and further fixing up of camp, we were startled by a sudden noise and looking up were more startled to see half a dozen bighorn charging down the mountain slope just behind us and directly toward us. They dashed right through our camp, swerving only a few yards to one side as they saw us and our little fire. It was breath-taking.

We found next morning that we had chosen for camp site a spot over which a number of bighorn trails ran from Specimen Mountain on the north down the slope across the little meadow on the pass and up the next mountain of the range to the south. So rarely visited was this region that the bighorn, with all their wariness, were not sufficiently startled by our presence to leave their regular trail by more than a few yards. However, no more such surprising visits occurred.

Next morning we set out and up on a reconnaissance and found that above timberline, which was only a few hundred feet higher than our camp, the steep slope of the old volcano was smooth and easy to climb. It led us directly up to the rim which ran evenly and almost completely around the great crater. Thus we could easily walk all around the crater, keeping just low enough below the rim on the outside to prevent any animals within the crater from seeing us. But it was easy for us to see the inside of the whole crater by merely crawling carefully up to the rim, and lifting our heads slowly up high enough for us to peer over the crater's edge.

The inside of the crater presented a remarkable sight. The bottom and walls were composed of old ashes and scoriae with some cliffs of shining basalt and numerous upstanding castles and pin-

nacles of braccia or volcanic conglomerate. Some of these stood up fifty or sixty feet from the floor or side walls of the crater and were twenty or thirty feet wide.

As we cautiously looked over the rim we were gratified to see a group of bighorn resting quietly on a sort of basalt platform jutting out from the crater wall. Two or three were lying down, two or three more were moving slowly about, while on a higher part of the platform was a fine old male with tremendous curved horns, standing rigid and alert, evidently the lookout for the band. We watched them admiringly for a few moments, when unluckily one of us, in trying to change position, pushed over the rim a loose stone which bounded down the inside of the crater.

Like a flash every sheep was on its feet and on the *qui vive*. Because we kept perfectly motionless, the big lookout could not be sure, for a moment, where we were, but taking his cue from the direction of the bounding stone he started up the precipitous side of the crater away from us, followed closely by all the others. It was a beautiful sight; their ease and confidence in swiftly getting over the rough steep going was impressive. In a few moments they were out of the crater, and, heading north along the mountain's upper flanks, they soon disappeared from our view. But we had seen bighorn close at hand, although too far for photographing, and felt that their fright had not been great. They would come back.

After they had gone, and we could stand up and move around the rim and survey the whole of the crater, I worked out a plan which I felt sure would result, if everything went according to plan, in getting some bighorn close-ups.

The plan was very simple and was suggested by the two facts, first, that one could move all around the rim, out of sight, and then come into sight wherever desirable, and second, that the great breccia castles ought to give one sufficient protection from being seen to allow one to work down into the crater, keeping one of these castles between one and any band of sheep that might be anywhere in the crater. Of course the wind would also have to be right—that is, blowing from the bighorn toward the stalker and not from the stalker toward the bighorn. They have a perfect sense of smell.

So the next day we all went up together again and, on peering over the rim, were wildly excited to see a band of nearly thirty bighorn in the very bottom of the crater. Almost between them and us towered a great breccia castle. The wind was just right to allow me to try to get down the crater wall behind the castle.

I began a hard and wearisome descent of nearly two hours, slowly crawling over sharp bits of basalt, rough blocks of conglomerate and beds of old ashes, keeping always that protecting breccia castle between the animals and me.

I finally got down to the base of the castle. This was as far as I could go. I was within a hundred yards of the band of bighorn, which had all fortunately kept close together. Behind the castle I waved a handkerchief to my carefully watching companions on the rim above, who immediately set off below the rim on the outside to a point just opposite where I had gone down. They were to scatter a little there, and then all to show themselves at once on the rim to frighten the sheep towards me.

It worked. I was ready with camera already pointed to that side of the castle which seemed the most likely to be chosen by the sheep in their flight.

I heard a clattering of hoofs and rocks. The noise grew louder. My companions added violent yells to be sure that I

knew the sheep were coming. I did know it. I couldn't help knowing it. I was growing violently excited. I held the camera at a ready angle. And then that magnificent band, led by two superbly-horned old males, dashed around the side of the castle, bearing directly toward me. I thought they would run over me. But they didn't. They swerved slightly and there they were, all lined up, broadside on, only twenty yards away. It was a picture made to order.

But, alas, it was too exciting. I had a bad case of buck fever. My hands jumped as the sheep did. I couldn't hold the camera still. It was no use. But I did manage to press the bulb.

That negative when developed and printed from yielded a picture of bighorn at close range. But every sheep in it is a blurred something with a dozen legs. No naturalist would recognize the animals on it. He would think they were centipedes. But I recognize them. It is my prize picture.

THE PROGRESS OF PUBLIC HEALTH IN CHINA

By Dr. REGINALD M. ATWATER
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A FEW months ago I was asked to vaccinate several hundred children against smallpox in a large but old-fashioned public workhouse located in a provincial capital of China. While there I saw a small beggar boy with badly infected eyes and cheeks stained a bright red color. He had been treated in a local mission hospital with a new germicide specially useful in such cases and by the aid of which his vision was saved. Less than five years before, the discovery of this special drug had been announced at a research institute on the other side of the globe from China and after prolonged study of this and related chemicals. In this short period of time its use had not only spread across the intervening miles of land and water and across national and racial barriers, but it had been made available to him, a penniless and homeless lad, through the aid of well-placed philanthropy.

This incident epitomizes to me some of the progress that scientific medicine and public health have made in China. It is not yet general over China, nor is the movement yet sufficiently indigenous, yet the growth in sentiment is a real thing.

A true perspective in the development of public health is indeed difficult of attainment in this day and age. It would be difficult to devise a method for getting a true perspective better than that open to the student of public health who lives in China and sees there the attitudes and methods which were a part of the lives of our own ancestors. One comes to a fresh appreciation of the heritage that is ours in this favored land. China's present slight regard for matters of public health may be compared to that of the makers of our own Constitution. It never occurred to these American fathers to include provisions for the federal control of health work, provisions which are now a part of all modern constitutions, and we should not be too hasty in requiring attention to these facts from the Chinese.

There is a well-known Chinese classical book on disease, the Shang Han Lun, written at about the beginning of the Christian era, and a book still commonly bought and read for its supposed value in treatment of diseases of to-day. This book is venerated because it is old and tried. It is not possessed of our much-admired newness or scientific accuracy. It is built on the classical and empirical methods of the old physicians. Between this book and a modern treatise on scientific medicine there is a gap scarcely to be bridged by one generation of Chinese, but the progress along this road is promising and apparent as well to one who has lived among the Chinese people.

It would seem appropriate to speak at this point of the much-quoted custom among Chinese of paying the doctor to keep the patient well and not paying him when the patient becomes ill. It would be interesting to know the origin of this report, for diligent search in China does not reveal any knowledge of the practice among the Chinese and nowhere is there evidence that the Chinese physicians have emphasized prevention of disease at all.

In enumerating those agencies which are promoting the public health in China to-day we may mention certain official bureaus of the government, such as the Manchurian plague prevention bureau and the epidemic prevention

bureau in Peking. Both of these agencies have grown out of the effort made in 1911 to stem the tide of pneumonic plague that threatened all central Asia, and at present they are making some progress, though the present areas where plague is endemic are left out of account. Sera and vaccines are now being produced in Peking under good auspices and a healthy growth has characterized the past few years. The national code of laws of the republic has some provisions for control of medical practise, but these are purely nominal at the present time and can not be said to do any good. Several Chinese cities have police health officers, so called, but these men almost without exception have not contributed anything, for they are untrained and ignorant of the best methods. One progressive city recently appointed a first-class, western-trained Chinese physician as health officer, but the political situation was such that his tenure of office was short and his work fruitless. And this is about all we can say for the official agencies.

There are some voluntary agencies which are promoting the public health, like the few good medical schools, a number of hospitals, which are becoming centers for the propagation of health ideas, and a modern health center in Peking. This latter is nominally maintained by the government and is a splendid experiment in adapting the preventive idea to China's needs. There is a Council on Health Education in Shanghai and there has been a Committee of the China Medical Association, both of which have aided the translation of scientific material on hygiene as well as the preparation of health propaganda material.

In connection with these voluntary agencies there may be noted several active health associations in the larger cities, some of which have paper programs as diversified as one of our western cities would have. There have been some interesting studies made in sewage disposal methods, in the distribution and control of hookworm disease, on schistosomiasis, on kala azar and in the development of useful drugs from the old Chinese pharmacopoeia. Advances in school and community hygiene, in educational hygiene and in health propaganda work of several sorts have been made by the Council on Health Education.

Famine and poor relief are not public health measures in the United States, but in China they are necessary directions of effort which take precedence over more refined measures for combatting the force of mortality. Of particular interest is a movement in Hunan Province which has sought to greatly improve the existing public measures for poor relief. Through the enlightened interest of one Chinese gentleman, methods have been so changed as to meet this problem in a fairly satisfactory way and his idea is being copied widely. The relief of poverty is indeed the keystone in the arch of public health.

To enumerate the contemporary agencies which are defeating the aim of public health will require a longer list. Most people would place governmental instability at the top of the list. To this must be added the militarism everywhere found, with its associated brigandage, wars, disorders, poverty, famine and the opium evil. The margin between the supply and the demand for food is very narrow and the actual famines which result from drought and floods are frequent and severe. The associated typhus and relapsing fevers and other pestilences that go with famine take their large toll of life.

The newer developments of industry in the large centers are bringing in laborers from the country who often have to live under deplorable conditions of sanitation. Hours of work are very long and work every day in the week is the rule. Child labor and the labor of

women are widely exploited. The nation is being pauperized in those elements of physical and mental well-being so essential to-day in the young and in women, who are the centers of family life. There is a total absence of maritime or border quarantine which conceivably might prevent the importation of exotic disease, and no semblance of a national census, which is such an essential link in any public health organization. The scarcity of hospitals of all kinds and the almost complete absence of tuberculosis sanatoria is a serious obstacle for both the present and the near future.

But perhaps the most significant of all obstacles is the inertia that comes from the firm adherence of these hundreds of millions of people to traditions which have been their heritage through thousands of years. These traditions in their time have been elements of great strength and have provided a racial solidarity that is scarcely matched in human annals. But the dependence of the masses on worthless measures for the preservation of health, the wide prevalence of ideas of disease which are demoniacal or worse, veneration of the old because it is old rather than because it is good, general distrust of the new because it is new, failure to understand or to profit by the scientific method, adherence to outworn usages and a fatal tendency to laissez-faire—these are the real obstacles to public health progress in China to-day.

Thus frankly stating the favorable and the unfavorable elements in the situation, just as we would wish Chinese to do in appraising our own conditions, we can see that ultimate success for public health will depend on adjustments in intellectual matters, on changes in governmental method, in commercial adaptations, in educational advancement and on changes in countless other aspects of human life. The very complexity of the situation challenges the interest of those who feel that the welfare of the whole race demands the welfare of China.

While it is true to say that governmental instability stands at the top of the causes which operate against public health, the more significant force is still the underlying continuity of the great stream of human life in the Middle Kingdom. Life in China goes on day by day and year by year largely unaffected by transient military and political conditions which would be serious complications in our life here. I found this true when I lived in a city of central China which was besieged for six weeks. During this time the city frequently changed hands and was in the zone of almost constant fighting. Yet the current of daily life was not seriously disturbed. Schools, colleges and business went on largely uninfluenced by the fact that shots and shells were flying overhead most of the time. The people took practically no interest in the struggle except enough to keep them from being involved in the difficulties. So to attain a true insight into the possibilities for public health in China we must to a certain extent overlook the surface disturbances of government that overhang most of these members of the yellow race and focus our attention on the broad current of human life which goes on under the surface storms and which so much needs improvement in healthful ways of living.

There is a different background for public health sentiment in the Chinese race and in our western make-up. Chinese do not spontaneously resent inroads on personal liberty as we all do here. Anti-vaccination sentiment is hard to raise among Chinese, particularly among people who depend directly on the life-preserving quality of vaccination. Toward certain racial poisons they have very different attitudes from ours. The overuse of alcohol is not common in China, even though unlimited access to alcohol is afforded to every one. Indul-

gence in opium, on the other hand, is more easily acquired by the Chinese race than by some other races. The whole background of sewage disposal in west and east is utterly different. Here sewage accumulations are a liability to the individual, who pays either directly or indirectly for their removal and destruction and who pays generously for methods which permanently remove this material from sight and smell. In China, on the other hand, the accumulation of excreta is an asset to the householder, who expects to receive payment for it, expects it to be used for fertilizing purposes and who is not seriously distressed by the sight or odor connected with the process of removal. If then we expect China to install water-carriage disposal of its sewage on the same plan as American cities, we do not count on very significant differences in the western and the Chinese situation.

There are also racial susceptibilities worth pointing out. Chinese who live where vital statistics are kept are known to suffer from respiratory and circulatory diseases more frequently than the Caucasian race. Thus in 1921 in the United States the comparative rates were as follows:

	Chinese in U. S. A.	Caucasians
Death-rates from all causes (per 1,000)	24.47	11.20
Tuberculosis (per 100,000)	526.3	85.3
Circulatory diseases	332.8	182.0
Respiratory diseases	238.8	102.8

While these figures may be subject to slight correction for differences in age distribution, the facts in the main are as indicated. Chinese very rarely have certain of the metabolic disorders, like diabetes, and it is believed that they have a racial immunity to diphtheria of relatively high degree, as do certain other races with pigmented skin. Chinese live on a lower level of blood pressure than we and rarely suffer from hypertension. They have a lower level of basal metabolism which may be associated with their easier way of life.

Thus there are known physiological differences which tend to alter disease prevalence and the methods of control must therefore be properly adjusted. These very differences between us and the Chinese may easily prove to be keys for the better understanding of some of our own chronic diseases. With the mention of these differences in background and method it is clear that in China there is the same public health goal to be achieved, but the successful approach to that goal will be different in some respects from that here.

One might speak indefinitely of the numerous differences between aspects of life in China and the west. After all, these differences are more apparent than real and more superficial than fundamental.

Two men in middle life, fathers of families, die from typhoid fever, one in China and one in America. At the funeral in China the mourning color throughout is white, while here it is black. The hearse is bright red there and black here. The music—there could scarcely be any greater difference between the music played at the Chinese funeral and that used here. Firecrackers will mark the occasion there while prayers will be said here—every aspect of the occasion will be marked by differences equally as great as those mentioned. Yet, beneath the ceremonies there and here is the same overwhelming grief to the wife and family, the same loss of educational and economic values to the community, the same dangers to those who have been associated with this perilous infection and the same preventable disease is responsible. There are no differences in the parasite that killed the two men; it enters and leaves the body in just the same ways, it spreads through similar channels, it damages the constitution of Chinese and

American in exactly the same fashion. The outward aspects of the two are very different. Looking more deeply we see their essential similarity and we realize that, when all is said, the resemblances of the two incidents are greater than the differences. Human nature and disease are much the same the world over: "The Colonel's lady and Judy O'Grady are sisters under their skin."

We might set down some of the diseases which are specially prevalent in China and which the rest of the world can well do without: plague, both bubonic and pneumonic; schistosomiasis; kala azar; clonorchiasis; relapsing fever; typhus fever; cholera; rinderpest; foot and mouth disease; severe smallpox; sprue; amoebiasis; leprosy and beriberi.

To make the list fair we should add certain of the diseases of the rest of the world which China does not have as we do and which she can well do without: yellow fever; Rocky Mountain spotted fever; poliomyelitis; pneumococcus pneumonia; pellagra; tularemia; dengue; trypanosomiasis, and we have already mentioned the rarity of such conditions as diabetes and high blood pressure.

It has often been stated that China is the ancient home of diseases like plague, cholera and influenza, which at certain times have spread to the rest of the world. The 1894 plague outbreak, the immediate precursor of the present pandemic of plague, did first come to notice in China. But usually it has been our ignorance of the real source of epidemics which has led us to assign their origin to those parts of the world where the prevalence of disease is least understood. There is, however, sound justification for the modern effort to track disease down to the places where it smoulders and, until China's health is made secure, the health of the rest of the world is in peril from China.

China can not be said at the moment to be progressive in directions which improve public health. One ought to note certain encouraging elements in the situation which portend a better day.

There is being created now in China a small but very influential body of well-trained physicians who are acquiring the idea of prevention along with other concepts of modern medicine. In this nucleus is the great promise of the future. These are the men who, with the facts of science, must make the adaptations of these facts to life in China and we must allow them freedom in adjusting these methods to conditions as they find them.

Among these Chinese medical men there are some to whom the preventive idea just naturally appeals. President Vincent has pointed out that this same thing is increasingly true in the United States. These peculiar men love to deal with humanity in the large; disease as a mass phenomenon appeals to them tremendously; they like social problems involving cities, provinces and nations; these men someway prefer a salary rather than the uncertain collections of private practice, and some of them have faced the difficult decision and have chosen the laboratory instead of the limousine—or we might say, have chosen the ricksha instead of the automobile. Foolish as it may seem, these men simply can't be kept from doing this type of public service, for they are endowed with sufficient imagination to see that there are significant values in preventing disease and death, even if they can not tell the names of those whose lives and health have been saved, a difficulty inherent in preventive work as against curative medicine.

To a large extent, the problem of public health in China is bound up with the application of known facts to human life. It is not primarily abstract research that is needed, but the study of social applications of the facts already known and it is reasonable to anticipate

large returns on investments in this direction.

There has been a decided improvement in the recognition accorded to scientific medicine in some of the areas longest open to modern medicine, now nearly a hundred years. One city has about 350 physicians trained in modern methods who are being accepted by the community in generous fashion. In other centers the need is to create an understanding of and a demand for scientific medicine. In a few of the larger cities there have been ventures in the direction of medical education, public health centers and campaigns for health on the part of the government, which are encouraging indications of a growing community interest. There has been progress in the recognition of the fact that gifts from wealthy individuals can play a part in public welfare. Chinese have not yet learned to give to institutions that promote the public welfare, but at least one Chinese merchant has endowed a university with a princely sum and a medical department will be opened here in the near future.

One hopeful line of research is that which seeks to find values in the drugs of the old Chinese school. These old physicians used such drugs as arsenic, mercury, the common cathartics and anthelmintics in blind fashion. Here is a mass of useless chaff and some grain and already out of this study has come one drug, ephedrine, and there are very likely other similar values waiting to be found.

Perhaps the most encouraging feature of all to-day is the rising tide of nationalism which has come to the front so strongly in the past few months. The outbursts of feeling which have occurred recently have frequently flared out against grievances both real and imaginary and the present accounting shows that some of the Chinese have not been too discriminating in their attacks on what has come to China from the west. But the Chinese are in the end a very sensible people who can not fail to recognize real worth when it is properly presented to them and we can hope that they will soon attain an insight which will allow them to preserve the best elements of that which the west offers China. No true friend of China can deplore the rise of this spirit of national pride, however much he may regret certain directions in which the fire has burned beyond reasonable bounds. It is this same spirit which will save China, and national pride will be a strong element in promoting public health reform. In her potentialities China is great and in these possibilities we can find hope for the future.

There was never a time in history when there was so great a disparity of knowledge and attainment in hygiene on the part of contemporary peoples as to-day between the east and the west. There is, therefore, an unprecedented opportunity which gives added point to the effort that is being made for the benefit of China, an effort that has assumed large proportions. In this time when so much can be accomplished by the application of the facts of science to human life, it is highly desirable that the aid to those agencies which are promoting the welfare of a quarter of the human race should be generous and sustained. The work has a self-propagating quality because of the reproductive capacity of the future leaders now chosen for training and the opportunity for unselfish investment of both personality and power in the form of money is very great just now.

To the end that in China as here

> Health may be more perfect,
> Life more vigorous,
> Disease less frequent,
> Decay less rapid
> And death more remote.

POLITICS AND THE PUBLIC HEALTH

By JAMES A. TOBEY

WASHINGTON, D. C.

THE chief problem of modern public health administration in this country is one of personnel. In spite of the fact that this branch of public service offers many fascinating opportunities for constructive effort, it seems impossible to secure an adequate supply of properly trained sanitarians. Medical students, sanitary engineers and other persons presumably well grounded in the fundamental principles underlying sanitary science hesitate to make public health a career. As reasons for their reticence they cite the inadequacy of the compensation, the insecurity of tenure and the fact that partisan politics frequently tends to retard real scientific progress.

For these criticisms there is, unfortunately, some justification. It is true that a competent and successful physician can earn more from the practice of medicine than he could ever hope to draw in salary as a health official. On the other hand, there are some advantages in the career of the successful sanitarian. His regimen of life can be much more regular than that of the doctor of curative medicine, his income is fixed and more or less certain, and his accomplishments are, or should be, more satisfying, for the results of his efforts are measured not by the relief, but by the prevention of disease. Public health means the highest type of public service. The administration of it needs, therefore, the finest kind of practitioner obtainable.

Public health is to-day a definite and distinct science and those who practice in this field are members of an actual profession, a new one, perhaps, but a real one, nevertheless. It is not a branch of medicine, though physicians like to look upon it as such. Nor is it a subdivision of sociology, though social workers make that claim. Neither is it a matter of engineering, though civil and sanitary engineers would have us so believe. It is no one of these but a combination of all of them and of some other branches of scientific knowledge. Public health draws upon preventive medicine, sanitary engineering, chemistry, sociology, economics, statistics, education, law and psychology for its component parts. This may seem fairly broad in its ramifications, but, while complex, it is no superscience. It is, to be sure, no field for the dilettante, but the sanitarian is not required to be a superman. Train the health worker properly and free him from the inhibitions of politics and he will, as a rule, produce results.

Public health, then, is the science and art of disease prevention, health promotion and life prolongation. It deals with man and his environment, both of which are controllable matters. It is based on experience, the accumulated wisdom of a science which has gradually developed from the foundation laid by the great Pasteur in the latter part of the nineteenth century. It has many positive achievements to its credit, though a few pseudo-scientists who have a sort of nodding acquaintance with public health sometimes scoff at these accomplishments and attribute the admitted improvement in national vitality entirely to the biological phenomenon of natural selection. The sanitarian, be-

ing more liberal, concedes that hereditary influences have played their part, but points to the mass of evidence which demonstrates the irrefutable significance of environment on salubrity, public and personal, and he therefore feels justified in demanding his proper share of the credit for lengthening the span of life.

As an instance of the control of the environment, typhoid fever presents a striking example. At the end of the nineteenth century this disease was often epidemic and as late as 1911 was taking an annual toll in this country of about twenty-one deaths per 100,000 population. The sanitary engineer was not only the epidemiologist who demonstrated the mode of infection, but also the eradicator of the disease who built proper sewage disposal plants and constructed devices to produce and maintain pure and potable water supplies. Thus, to-day the death-rate from typhoid fever has been reduced by two thirds, to less than six per 100,000. The sanitary engineer has done the same service with the mosquito-borne diseases, malaria and yellow fever, and has likewise almost banished hookworm from North America. The laboratory worker has developed methods of immunization against diphtheria and, recently, scarlet fever, so that to-day no one will die of these diseases, unless so utterly deluded as to let a chiropractor try to treat them. Tuberculosis is, perhaps, the most remarkable example of the conquest of communicable disease, because twenty years has seen its mortality more than cut in half, from nearly two hundred in 1900 to about ninety in 1922. Many factors, economic as well as sanitary, have undoubtedly contributed to this result, but no small part is due to the efforts of the expert public health worker.

All in all man seems to be getting the best of the microbe. His achievement is, moreover, measured by his skill. This is shown by the fact that conditions vary widely in different parts of the country. The biologist may endeavor sardonically to explain this by variations of race, of climate or of anything but sanitation. His explanations do not hold good in the face of the facts, however. When Berkeley, California, can have an infant mortality rate in 1921 of thirty-nine deaths under one year of age per one thousand live births, while Fall River in the great states-rights-frenzied Commonwealth of Massachusetts has a rate of 114, something other than heredity is to blame, especially when it is considered that New Bedford, a municipality quite similar to Fall River, has a rate nineteen points below the latter's 114. When Minneapolis can attain an infant mortality of fifty-six and certain other cities of similar size do not, again the guilt must fall not on natural selection, or its failure, but on environmental conditions, which are controllable. New York, a conglomeration of diverse nationalities and racial strains, reduced its infant death-rate from one hundred and forty-four in 1908 to eighty-five in 1920.

The factors over which sanitarians have not had so much control, and which any sensible person, except a eugenist, perhaps, will admit have had an effect on public health, comprise such matters as the increased economic independency in this country, with its concomitant improvement in housing, nutrition and medical care; the advantages of better educational facilities, resulting in a more widespread understanding of personal hygiene, though, as Dr. Haven Emerson has appropriately remarked, we know infinitely more than we use; and finally, perhaps, a gradual immunity to certain maladies, brought about by natural selection.

In the last analysis, however, the development of public health gets back to a question of men. The great sanitarians like Gorgas and Sedgwick did great

things because they were the men that they were. Both are dead and at the moment there is no one in their places. Welch and Vaughan and Chapin, who have been among the leaders, have nearly reached the retirement stage and very few are in sight as yet to fill their places. There are only a dozen reputable schools of public health in this country and they do not seem to entice vast numbers of candidates for this attractive career. In 1923 there were graduated from the Harvard School of Public Health, the School of Hygiene and Public Health of Johns Hopkins, the course in biology and public health of the Massachusetts Institute of Technology, the graduate work in public health of the University of Michigan and the public health courses of the Yale School of Medicine, to mention the leading institutions, just sixty-seven persons. The total for all schools of public health in 1923 was eighty. Many of the students in public health at Harvard and Johns Hopkins are induced to go there by scholarship grants from the Rockefeller Foundation, which has endowed these two schools, and a large number of the students in both these institutions are foreigners who return to their own countries after completing their courses. It is estimated that there are at least twenty thousand positions in this country in official or unofficial health work, though, of course, most of them are now occupied by so-called sanitarians.

The type of men and women in these positions are mostly those who have been trained in the school of experience, which is often rather good instruction. Sometimes, however, the training period, where there is no foundation, is a trifle detrimental to the welfare of the public. A recent survey made by the American Public Health Association showed that 7 per cent. of the health officers of seventy-two cities having a population of one hundred thousand or over had received neither college nor professional training. In a list of over seven hundred city health officers, issued by the United States Public Health Service, only ten are noted as having degrees in public health, such as the doctor of public health, or the certificate of public health, though undoubtedly there are others who have been specially trained but are too modest to list such degrees as they may have received. Similar conditions of lack of positive training obtain in state and county health departments. Of course, there are plenty of capable and efficient health officials who have been well educated in the university of hard knocks. There is a goodly number, however, who have not derived any particularly useful erudition along public health lines from this source, who might have been benefited by the proper kind of a college course in sanitary science.

So much for the lack of training. When the tenure of office is examined, it has been discovered by the United States Public Health Service from a recent inquiry that over one half of the state health officers concerning whom the report was made had served less than five years and that of the number now employed over forty per cent. had held their present positions for less than two years. In Texas, for instance, the state health officer changes so frequently that no sanitarian in other parts of the country ever has the slightest idea who is the present incumbent. This is no sarcasm, but is literally true. City health officers are also often short-termed officials and frequently survive only for the duration of an administration and sometimes not that long.

Two factors are involved in this matter of tenure. One is the paucity of the average salary paid to health officers, the other is the baneful influence of politics. The present orgy of economy which, due to the stimulating influence in the nation's capital, is now sweeping the country, is kicking against the pricks

when it comes to expenditures for public health, for they have never in the history of sanitary science been anything but extremely penurious. A study of the budgets of 187 American cities in 1921 showed that the per capita expense for health purposes was only seventy-one cents. For the "promotion of cleanliness," such as street cleaning, rubbish disposal and other similar branches of municipal engineering $2.50 per capita was spent, while $10.62 went into education and $2.57 for fire protection. Naturally, under such conditions, compensation for the official guardians of the public health is not lavish. Three years ago the Committee on Salary Standards of the American Public Health Association recommended that the minimum salary for a state health officer should be $5,000 a year, which is a reasonable figure for the importance of the duties and the preparation and skill required. The actual salary paid averaged only $4,453 for all the states. Economy may be a good thing, but when it comes to a choice of spending many millions for hospital and institutional care of the physically and mentally defective as against thousands of dollars in order to prevent the conditions which call for these relief expenditures of millions, any person with any vestige of intelligence whatsoever ought to be able to realize that the ounce of prevention is worth more than the ton of cure.

Security of tenure has, of course, two sides to it. Tenure should not be so adamantly secure that unqualified persons can remain interminably in office and on account of their unfitness hamper progress in public health work. Health officials should, nevertheless, be allowed to hold their positions as long as they produce beneficial results and they should never be subject to the caprice of politics. At present the insecurity of tenure is notorious, like the treaty of Alcibiades, famous because it is so infamous.

"The care of the public health should be the first duty of the statesman," is an oft-repeated aphorism, attributed to Benjamin Disraeli. Other masters of statecraft on both sides of the Atlantic have unburdened themselves of similar lofty declarations. From the days of Empedocles, who is said to have been the first sanitarian, to the present time, the customary manner in which statesmen have cared for the public health seems to have been to hinder as much as possible the sanitarian in his humanitarian endeavors. The biography of Gorgas is an account of a life-long struggle against petty and less petty annoyances placed in his path by pin-headed politicians, who had no conception of the immense value of his efforts, nor appreciation for his self-sacrificing devotion to a cause which played no insignificant part in the construction of the Panama Canal. Roosevelt had sense enough to back him up when Shonts tried to shunt Gorgas into obscurity and put an osteopath in his place, but later Goethals apparently never did cooperate effectively or credit sanitation with making possible his own remarkable engineering achievements.

The manner in which various and sundry so-called statesmen have "cared" for the public health is illustrated by a number of illuminating incidents, all actual occurrences within the last few years. When one of the recent mayors of Boston was running for office some few years ago he pledged himself if elected to remove the health commissioner as his first official act. This in spite of the fact that this health commissioner was a well-trained, capable administrator, who had been honored by his profession by having been elected to the presidency of the American Public Health Association, the professional society of sanitarians of North America. The candidate was elected and this health officer resigned promptly, or he would have been ousted just as promptly. Of course, his honor could argue that he

would accomplish more by having a subordinate who was persona grata to him, and it is true that this mayor has subsequently shown a decent interest in public health, but the general principle is wrong, nevertheless. As a contrast may be cited the example of Savannah, which some time ago asked the United States Public Health Service to conduct a competitive examination for a health officer, to be chosen entirely on merit. In the announcement of this examination it was stated "the position is guaranteed free from political interference."

Sometimes the health official who finds it expedient to change jobs when the administration shifts is better off in the long run. Recently the health officer of Kansas, who had effectively administered his department for nearly a score of years, was replaced when a new governor was elected. It so happened in this case that his successor was a competent sanitarian, though that does not alter the evil principle. The ousted official was promptly deluged with offers from other sources where his ability was appreciated and he is now the executive of a national voluntary health agency, of which Mr. Hoover is president, at a much larger salary than he probably ever would have received from his native state. On the other hand, it is not always a simple matter for a professional man, like a sanitarian, to step immediately into a new position after he has been relieved of his emoluments in another.

Numerous other regrettable incidents where politics has played havoc with the public health could be cited for all parts of the country. In Richmond, Virginia, a health official who had built up one of the best health departments in the country over the course of twenty years went out a few months ago because, as a caustic editorial in the *American Journal of Public Health* put it, "the voters preferred one mayor to another." In Philadelphia a competent director of sanitation was supplanted by a real estate man. These unfortunate incidents are luckily balanced now and then by more pleasant ones. The late Dr. Herman M. Biggs, for many years health commissioner of New York, was appointed by a governor of one political faith and kept in office by other governors of various political affiliations because he was acknowledged to be the best qualified man for the place. At the time of his death the deputy health commissioner was properly promoted to his place by the present broad-minded executive of the Empire State and it is fairly certain that politics had no influence in the matter.

North Carolina is a Democratic state, but it has at least one district which frequently goes Republican. On one of its lapses from this desirable or undesirable condition, depending upon one's point of view, it was proposed to replace the efficient county health officer with the only physician who had voted the winning Democratic ticket and who, incidentally, had no public health experience. The incumbent was apparently a Republican. The stage was all set for this inspiring spectacle when the Democratic state health officer, one of the best in the country, appeared on the scene. His pronouncement was something like this:

"Gentlemen, you can replace this capable health officer if you like, but I warn you that you must also replace his record. If you do not do so, the State Department of Health will hold you accountable." That put a different aspect on the matter, especially when the proposed candidate, to whom the situation had also been explained, voluntarily came forward and insisted that the health officer be retained. He had previously had the erroneous idea that the office was merely a political plum. It should be, of course, anything but that, but too often it is only that. When such

is the case, is there any wonder that some public health administration is full of waste motion and ineffective operation?

Since the record of an official is the criterion of his effectiveness and the one item which is occasionally irreplaceable, an attempt is now being made to evolve a system of appraisal for health departments. A rating standard has been worked out by the American Public Health Association, with the cooperation of other voluntary agencies, such as the American Child Health Association, and is now in actual use. This appraisal form was considered by a group of municipal health officials themselves, who conferred about it in a strenuous way for nearly a week last winter. Thus, this scoring system represents the consensus of professional opinion and when the public health activities of a community are determined by it, a scientific measuring stick has been applied. After this appraisal form has been in actual use for a year or so, it will be revised in the light of experience and will be then issued in a practically permanent form. The employment of such standards in evaluating the public health accomplishments of an official will undoubtedly be of much value in coping with the usually pernicious influence of politics in public health.

Another solution in the taking out of politics from public health is to put statesmanship into the science. Statesmanship is merely politics in an ethical form. The average scientific man is too often prone to be an amateur in political science. That is one reason why practicing physicians frequently do not make good health officers. A health official who knows how to deal with all kinds of people, especially other officials, can achieve scientific progress, provided, of course, he has some conception of the latter. This has been well demonstrated in cities like Bridgeport, Connecticut; Memphis, Tennessee; Detroit, Michigan; and the Oranges in New Jersey, where well-trained health officers with the right kind of a personality have managed to get along smoothly most of the time. It used to be the boast of the next before the last health commissioner of Chicago, before he succumbed to a reform administration, that he was the biggest political asset that Mayor Thompson had. He was, and not too bad as a health official, either. The voters of New York recognized the political acumen of the health commissioner of their largest city by sending him to the United States Senate. The keynote of the whole situation, then, is one of men. That means also that it is one of personality. Public health in the United States had made remarkable progress, but it can and will accomplish even greater and more alluring results when there is a copious supply of well-trained sanitarians, recognized as scientific individuals practising a dignified profession in a reasonable way, enhancing the national vitality and happiness of the citizens. When such men are available they must be provided with a decent compensation for their illustrious (let it be hoped) efforts and a tenure of office based entirely on merit. The time to divorce politics from public health, however, is now.

EXCURSIONS IN EXPERIMENTAL PSYCHOLOGY

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EVERY experimental scientist is a kind of explorer or prospector. He spends his energy pushing his way here and there into the darkness of the unknown, blazing trails which may or may not lead to scientific treasure. Unlike the geographical explorer, he is relatively free from mortal danger, though not entirely free from perils that give a tang of adventure to his work. He may get lost in the chaos of details and never emerge. I have known such lost souls. He may spend his time in fruitless quest, following trails that lead nowhere, at the peril of a wasted life. He is not altogether free from the peril of combat. He may find himself in conflict with his colleagues or with the native inhabitants of the dark continent of ignorance, who voluntarily choose darkness rather than light and prefer prejudice to information. Not all of them live in Tennessee.

Many of the joys of the explorer are within his reach. The struggle for truth is never tame, and the joy of pitting one's intelligence against the unknown and trying to do impossible things is only less than the joy of occasional discovery. None of these satisfactions is ever quite so good second hand. The classic rhyme about the purple cow, "I'd rather see than be one," is reversed in the case of the scientific explorer, "I'd rather be than see one." But there is some joy in hailing fellow prospectors in the desert or mountains, the classroom or symposium, and swapping experiences.

Two questions are naturally asked when prospectors meet. The first is "What are you prospecting for?" And the second is "What have you found?" Now, according to human nature, prospectors who are looking for the same thing are more or less suspicious of each other. They tend to regard each other as rivals or competitors. On the other hand, prospectors who are looking for different things are apt to be a trifle contemptuous of each other. The trout fisherman doesn't like to see another fishing the same stream. If he is ahead of him, he may catch the fish and spoil the fun. If he is behind him, he may catch fish and make his predecessor look ridiculous. Both fates are unpleasant. Furthermore, trout fishermen commonly have a sublime contempt for the stranger who is fishing for bullheads or hunting butterflies or haying in the hot sun or even prospecting for gold. These aren't his ideas of real sport. So it happens that we are apt to be either a bit suspicious or a bit intolerant of our fellow travelers. But true sportsmanship curbs both the suspicion of rivals and the contempt for other interests.

Scientific exploration aims, not at amusement or profit, but at valid descriptive equations. Now there are two main types of description—the particularizing and the conditional.

PARTICULARIZING DESCRIPTION

To say this man is John is an entirely arbitrary but useful identification of an object of thought, but it is empty of content. To say that John has certain peculiarities of gait, countenance, manner of thinking, inheritance and educational background gives us real information about him. If the particularizing is

complete, it may be expressed in a scientifically adequate descriptive equation. That is to say, it is reversible. The man with all these peculiarities is John.

The most common fault of particularizing description is its incompleteness. Some prominent feature of the situation is apt to *dominate* attention to the exclusion of the less conspicuous factors giving rise to a kind of presocratic simplification of the facts, the illusion of the "nothing but." You remember how the first great Greek philosophers decided in succession that the universe was fundamentally nothing but water or air or little atoms of various shapes or eternal flux. The situation was not essentially different from that of the blind men who went "for to see the elephant" and who confidently decided, each from his own point of contact with trunk, leg, ear or side, that the elephant was nothing but a rope, a tree, a fan or a wall.

There have been many presocratic simplifications in the history of scientific and pseudo-scientific description. Not so long ago the universe was commonly held to be nothing but matter in motion. Matter recently seems to be disappearing, like the Cheshire cat, till nothing but the motion remains. The latest fad of the pseudo-scientific is the dogma that man is nothing but a kind of ape and the universe is nothing but a group of electrons.

Psychology has passed through similar periods of simplification. Mental phenomena have variously been held to be nothing but sensations and their complexes, or reflex arcs, behavior patterns or configurations. The latest fad in uncritical simplification seems to be the sex urge or the libido.

Obviously such crude judgments fall far short of the ideal of scientific description.

Dynamic Description

In a sense no mere particularization can ever be adequate description. An organic whole is never the mere chaotic sum of its parts. Somehow in the living organism those parts are integrated. And in the scientific description of the organism the principles of its integration are just as important, perhaps more important, than any attempt to enumerate its parts. Complete description can not ignore either the parts or the dynamics of their integration. The first we called particularizing; the second we may call dynamic description.

The chief traditional faults of the second type of description are, on the one hand, picking out some prominent antecedent and calling it *The Cause* of a phenomenon; and, on the other hand, assuming some mythical entity like faculty, instinct, general intelligence or personality as the sum total of all conditions. The first fault is amateurish, another case of crude simplification. Without adequate description the second has the futility of an empty name. While we can describe only one thing at a time, science demands just as rigid criteria of completeness in dynamic as in particularizing description.

No one can say that either of these two kinds of description is more important for science than the other; but, speaking for myself, things and events seem most interesting and most significant when they can be made to serve as indicators of their more remote and hidden conditions.

Regarded as indicators, almost infinitesimal and apparently trivial facts may become of vast scientific importance. The slip of a mountain measuring only a few inches tells the geologist of subsurface stresses and strains that may mean future earthquakes. The microscopic shift of spectral lines tells the astronomer the constitution, speed and age of distant suns. The microscopic measurement of diffraction rings tells him their distances. The business of modern astronomy is not merely to name the stars or count them or describe their ap-

pearance, but to arrange for painstaking and accurate measurements that shall indicate the underlying dynamics of the universe.

Neither particularizing nor dynamic description is ever final. Particulars can always be regarded as smaller wholes which might be further particularized if we had better techniques. Conditions can always be regarded as the consequence of more remote antecedent or underlying conditions. Each step in the particularizing or the dynamic study of phenomena always leads to further possibilities in the development of science and frequently to new fields of practical exploitation. I find that a study of the conditions is not only the more fascinating, but I believe it is likely to be the more fruitful in the conduct of life.

All my scientific exploring has been directed towards the most complete possible recording of significant behavior, not for itself alone, but for the sake of finding out what makes the thing work.

Eye Movements as Indicators

My first scientific exploring expedition into the dark continents of psychology was in the general field of language, especially in the psychology of reading. There is no time at present to describe in detail the things we found and the things they indicated. In collaboration with my great master and friend, the late Professor Benno Erdmann, the Psychologie des Lesens gave scientific importance to the accurate description of eye movements as opposed to the then current assumptions. Simple observation of the eye movements first indicated what have now come to be regarded as some of the fundamental characteristics of the reading process, especially the apprehension of word forms and the size of the reading field at the reading pauses. More accurate photographic records showed the significance of prefixational vision, individual differences in reading habits, the maturity of reading development and familiarity with text and text parts. They proved to be useful indicators in neural disease, especially in the catatonic form of dementia praecox. They are the most reliable signs of alcoholic intoxication. They served further in the analysis of the fatigue process, in the study of habituation to rotation, and have recently furnished the first recorded picture of neural rivalry and competition. This last deserves more than mere passing description.

If a person is rotated clockwise in a revolving chair, the eyes show a reflex compensatory counter-clockwise drift, with jerky returns to positions of less strain. The latency of this reflex compensatory drift, that is, the time interval between bodily rotation and the beginning of reflex eye-movement, is of the order of 60σ. Without vision the accuracy of compensation is seldom very high. The eyes will start quickly to move in the right direction, but adequate compensation requires the elaboration of data that the semi-circular canal reflex lacks. There results a kind of stratification of the eye behavior. Beginning as a reflex the overt act imperceptibly passes under control of higher centers. I sought to render this transition explicit by rotating the environment in the wrong direction. It was an intriguing question as to which would dominate, the fundamental reflex or the less stable pursuit reaction of the eyes. The records show that reflex compensation always comes first and passes slowly and with more or less hesitation into an adequate adjustment to the moving environment. Immediately when the visual perceptual data are shut off, the fundamental reflex snaps back into dominance at the same stage of adaptation that it would have had if it had not been interrupted. When controlling vision of the unusually moving environment returns, the higher ares regain dominance slowly, gradually and often with a moment of hesitation. If the rotation is rapid enough to make

clear vision of the environment difficult and to correspondingly exaggerate the reflex stimuli, the period of hesitation lengthens and develops into a protracted episode of utter confusion and mal-adaptation which is characteristic of mental abnormality. I conjecture that this experimental procedure would yield important indicators of sub-normal cortical action. It should provide data for the early diagnosis of the dementias. However that may be, it is probably most useful just now as a paradigm of the interaction between instinctive action and rational control, the first experimentally recorded picture of the conflict and rivalry of cortical and sub-cortical centers for control of a final common path.

Integrative Consequences of the Refractory Phase

A scientific exploration which disclosed still more fundamental processes was a study of the results of repeated or continuous stimulation. It has gone somewhat slowly, extending over several years, and is not yet ended. The most intriguing and significant feature that I have to report is the integrative importance of that complex of metabolic processes which may for convenience be grouped under the concept of the refractory phase. The imbecilic knee-jerk will serve as a base of departure.

If one gives a sharp blow on the patellar tendon just below the knee cap, there results a contraction of the extensor muscle of the thigh, which constitutes what is known as the knee-jerk, or the patellar reflex. If that is measured, not by the movement of the leg, but by muscle thickening, the recorded curve shows first a little excursion at the moment when the blow is struck; then, a sharp rise at the moment of reflex thickening of the quadriceps muscle, and finally a gradual irregular decline, as the muscle slowly resumes its normal tonus or thickness. The time relations are significant. Between the moment when the blow is struck and the reflex thickening, there is a latent period of about .04″. The reflex thickening lasts about .04″ more, and the gradual decrease in thickening to normal lasts about half a second. If, after the muscle thickening is complete, the patellar tendon is struck a second blow, one gets a similar mechanical vibration from the blow, but no reflex thickening. The second blow came at a period of relative inexcitability of the reflex arc, and the lack of reflex response is an indicator of what is commonly called a refractory phase. If the second blow occurs somewhat later in the course of muscle relaxation, the response is proportionately greater. If it comes just after the relaxation of the muscle is complete and the curve has returned to its base line, the second reflex thickening is greater than the first. This is the phenomenon of the rebound. It indicates a period of increased excitability of the reflex arc which follows its recovery from a previous refractory phase.

Refractory phase or a period of relative inexcitability of irritable tissue after its reaction was originally discovered in the heart muscle by Kronecker and Stirling and was graphically recorded for the first time through the genius of Marey. Since then the refractory phase has been found in irritable tissue wherever it has been sought with adequate techniques. In nerve fiber it is extraordinarily short, of the order of .002″ to .007″. It has been found in isolated muscle, in the reflex closing of the lid, where it has a duration of two to three seconds, and in the swallowing reflex. In short, it seems to be a characteristic of all living substance.

The exact place of origin of reflex refractory phase is an interesting physiological problem. Obviously, a refractory phase of two to three seconds can not be a function of the axone, since that has an absolute refractory phase of only .002″. There is similar evidence that it does not reside in the muscle. For the same

reason it is obvious that it does not reside in the final common path. Moreover, voluntary contraction may precede or follow reflex contraction without decrement. There is a consequent general presumption that it is a phenomenon of the synapses between the neurones, and that in some way, still unknown, the irritability of some link in the chain in neural happenings is depressed by a previous excitation, while later the irritability is increased in the rebound after the original equilibrium has been restored.

I have a suspicion that similar synaptic changes are very widespread phenomena, producing corresponding changes in our experience and behavior. It seems probable that something similar to a refractory phase follows every cortical act, limiting its repetition or at least tending for awhile to make repetition more difficult.

If the Verworn-Lucas theory is true, refractory phase is the fundamental condition of inhibition. The phenomenon may be illustrated by the action of the knee-jerk to a rapid series of stimuli. If the stimuli succeed each other within the refractory phase from three to ten per second, there is a corresponding decreased reflex response which becomes complete inhibition at the higher frequencies. That is to say, at a frequency of ten stimuli a second, the first blow only evokes a normal reflex. The second and subsequent reactions are much reduced or may be entirely lacking. In the latter case a curve of the muscle thickening shows only the mechanical vibration in response to the blow without any reflex reaction.

Unfortunately this schema does not immediately apply to inhibitions in mental life, as the following illustration will show. If one tries to recall an unfamiliar name, the emergence of a wrong name may for a time delay the recall of the right one. Such a case offers no analogy to the inhibition of the knee-jerk through the development of a refractory phase from an antecedent reflex, since in this case the right name is not available even for an instant. Some mechanism must be at work which prevents the necessary neural action without first introducing it to develop a refractory phase. The question led to an experiment crucis. Would it be possible to develop refractory phase by stimuli which were too weak to evoke an overt response?

Experimental trial gave a positive answer to this question, both in the knee-jerk and in the lid reflex. By properly graduating the stimuli, beginning with faint stimula and ending with a stimulus that under ordinary circumstances always evoked an overt reflex act, the response was regularly decreased and occasionally failed to appear at all. This experiment not only seems to confirm the Verworn-Lucas theory of inhibition, but to explain many cases of what is commonly called adaptation in everyday behavior and experience. For example, one may get used to stimuli that would otherwise be very serious in their reaction consequences, provided the stimuli are increased to maximal proportions by gradual steps. Styles that now seem quite normal and natural would not have been tolerated if they had come suddenly. The Navy develops its gun pointers for the big guns by gradually increasing the caliber of the guns that the enlisted man is permitted to fire. Whenever this precaution is not taken, gun shyness is sure to develop from the noise and recoil. Orchestral volume that would be annoying to the listener if it came suddenly may reach the same intensity in a crescendo by gradual increments and be thoroughly enjoyed. One may indeed become almost intoxicated by noises whose volume would be intolerable except by slow increment. I vividly remember an Easter morning when I approached the ringing chimes of the Cathedral at Innsbruck. As I came nearer and nearer, it seemed as though

the noise couldn't be intense enough. I demanded more and more, and when I was finally standing under the bell tower I had an almost irresistible impulse to climb the tower to get more of that noise. You may have felt the same during a Tschaikowsky crescendo. The phenomenon has many analogies in experience and conduct. A climax is usually reached at last when the stimuli reverse the feeling tone.

One might ask what would happen to a reflex pattern which was made up of several partial reactions of different refractory phases. Suppose, for example, analysis of a given reflex pattern showed that it was composed of three acts, A, B, C. Suppose also that the refractory phases of B and C were, respectively, two and three times that of A. It seems probable that, if adequate stimuli are repeated sufficiently frequently, B and C will be temporarily eliminated from the overt response, leaving A alone with its relatively short refractory phase. As a matter of fact this supposition proved to be true in at least one instance where the records are entirely adequate, as the following experiment will show.

I was watching a guinea pig one day with my young friend, Mr. Louttit, when we observed an interesting and suggestive modification of its behavior. When I clapped my hand once only, the pig jumped or started in a manner which we found difficult to describe from simple observation. It also jerked its ears downward and backward. If I kept on clapping, it ceased to jump and merely jerked its ears. If the clapping continued long, fast, and loud enough, the animal ceased to jerk its ears, laid them back in tetanic contraction and started to run. Superficially it looked like a phenomenon which would be classified in the traditional psychology of learning. He might be said to have learned that the clapping of the hands was harmless and that, consequently, he ceased to jump or start and developed a complex protective response. This would be a reasonable explanation of his covering the external meatus with the ears and running away from the noise.

But we were suspicious of this interpretation, since the whole performance could be repeated after a short interval and since the animal ran in any direction in which he happened to be pointed, including the direction of the noise. The phenomenon seemed worth investigating, so we invented a device to record it. You may be interested in the details of its construction.

In front of our silent photographic recorder we suspended a light basket carriage on two point bearings and a spring. When the animal was in position in the basket, this balanced carriage brought a thin wooden offset into the beam of recording light, casting a shadow across a slit in a screen, which otherwise covered a sheet of sensitive photographic paper. The shadow remained stationary when the animal was still, but moved up and down the slit when the animal moved. Such a recording device is practically frictionless, has very low latency and may be made to have great sensitivity. Our recorder showed initial trembling of the guinea pig. One could count his respirations and occasionally we observed what we took to be his pulse, though this latter was not confirmed. A noise-producing instrument, also situated in front of the photographic recorder, was fitted with a similar offset, whose shadow fell across the upper part of the same slit. The recording light and the shadows of the offsets falling across the narrow vertical slit or rather a lens system, which amounted to a slit, fell upon the sensitive paper as it was moved evenly behind the opening and developed into horizontal shadow records of the sequence of events. The interruption of the recording beam of light by a toothed wheel, driven by a tuning fork, furnished time ordinates .01″ apart.

The resulting records entirely confirmed our suspicions. The latency of the start reflex varied between .02″ and .03″, while its refractory phase was absolute within the limits of our records, which were of the order of .5″. A thin recording lever laid across the ear gave comparable records of its reflex movements. They showed an amazingly low latency of the general order of .015″ to .018″, with a refractory phase that was not longer than .65″. These records proved that we were not dealing with a true learning process at all, but with a modification of the reflex pattern at a very low level of integration, determined primarily by differences in the refractory phases of the several components. The final step is still in the hypothetical stage. We do not know precisely what made the animal run when the stimuli were of higher frequency and intensity. It looks like a summation process by which otherwise inadequate stimuli reach levels of response which are usually inaccessible to single strokes. It seems to me that the phenomenon is not only interesting in itself, but indicates a principle of very wide application to the phenomena of conduct and experience. It is at once an explanatory principle for understanding life as we find it and a primitive condition of the integration of human behavior.

Just what I mean may be illustrated by another experiment. In connection with a long and very tedious study of the effects of repetition of stimuli at different levels of the nervous system, which was undertaken with the help of a subsidy from the Ernest Kempton Adams Research Fellowship of Columbia University, I found that a refractory phase occurred in systems of reaction where it might be least expected. I discovered it in the ordinary course of those anticipatory reactions which we commonly call learning by insight. Let me repeat a simplified experiment with your cooperation. I shall spell a series of words backwards. Please speak them out loud as soon as you know what they are. N-i, s-e-y, d-a-r-b, e-g-a-p. You more or less readily reintegrate the succession of letters and respond with the words *in, yes, brad, page*. If I were now to repeat the experiments and begin n-i, you would no longer have to wait for the completion of the adequate stimuli. You would anticipate them and might react by saying the entire series of words before I had spelled the first one.

If the words were then spelled through backwards once again, you would probably sit back in a complacent attitude waiting for something new. Your task is done. For some reason or other the reaction systems have become relatively inexcitable after the first response.

There is something strange about this relative inexcitability of the paths of recent responses. Since recency is commonly regarded as one of the most important conditions of recall, the reaction systems on the basis of traditional psychophysiology might be supposed to be in a strategic condition for immediate repetition. Why are our last acts not commonly repeated indefinitely after the initial operation? A relative refractoriness of neural systems would have double teleological value. It would be at once a protection against monotony of behavior and would open the way for new and more adequate adaptive responses. If recency of reaction resulted only in the increased irritability of a neural system, the first chance reaction would tend to be repeated interminably. It is a kindly fate that each neural event contains in itself the conditions of its suppression as well as those of its repetition. The consequence of this interplay of tendencies is eternal change, even in the relatively stable patterns of behavior which we call habit and custom.

Occasionally emotional reinforcement develops behavior patterns of extraordinarily low refractoriness. There results a consequent stereotypy in thought or

behavior which may on occasion assume pathological features and result in exhaustion. Occasional suppression of competing systems permits another kind of behavior pattern of extraordinary simplicity. The consequent sterotypy is of a different order from that which is produced by low refractoriness. Its most characteristic feature is stupidity. Relative fixity of behavior for lack of competition is a phenomenon of depressed intellectual activity or senility, whether it is found in an individual or a race.

How long does relative refractoriness last after initial reaction? There is probably no universal answer to this question. Each event and apparently each factor of an event has its own individual peculiarities of latency and refractoriness. Ordinarily in oral or written discourse one does not repeat an important word within the sentence, a phrase in the paragraph, or any paragraph at all. Still less do we care to hear or read such repetitions. We seldom read a novel twice. A repeated joke or story is a bore except to the narrator. With respect to many of the phenomena of repetition, however, there is a common difference between motor and perceptor refractoriness. I had a much loved friend whose one weakness used to be the persistent repetition of witticisms. He regularly laughed at them. They apparently seemed mighty good to him. His audience often laughed too, but chiefly through the reinforcement of loyalty or affection. One's wife and one's students not infrequently become similarly conditioned.

Analogous differences between motor and perceptor refractoriness appear in connection with a great variety of events, from the repetition of favorite words and phrases, the blowing of penny whistles and the explosion of firecrackers to the reading of scientific lectures and the representations of art objects. There seems to be a peculiarity of great art, however, that decreases perceptual refractoriness as well as motor.

It may be objected by some of you that we have no direct evidence for decrements in central irritability of any such duration as I have suggested. I maintain on the contrary that we do not lack evidence for such persistent changes of irritability in cortical reaction arcs. There are many phenomena in the psychology of learning that indicate long enduring changes in the readiness of systems to react. This involves some change in cortical tissue which is lost only slowly or not at all. Flashes of insight can at present be understood neurologically only as modifications of the synapses, which are practically permanent. Since all memory involves negative changes as well as positive, the elimination of competing associations can be thought of neurologically only as more or less permanent depressions in the irritability of the respective neural systems. It would be idle to speculate on the precise mechanism of such neural changes. It is physiologically unknown. Hypotheses of retraction of synaptic endings, of chemical blocking substances, and of change in the resistance of semipermeable membranes have all found some measure of acceptance. None is established or has achieved any high degree of probability. It is perhaps sufficient for our present purpose to realize that such increases and decreases of irritability are facts as well as problems.

Somewhere, somehow, the recovery of irritability is delayed in neural systems just as surely as it is in nerve or muscle fibers. There is some evidence which points to the localization of these modifications in junctional tissue or at the synapse. Refractoriness at any point in a system would tend to depress or even prevent the reaction of that particular system to a renewed stimulus. This does not mean that any factors in the system are fully paralyzed. They may react to

different or to stronger stimuli. They may react to the same stimulus in a different constellation. Common experiences as well as our experimental facts fit best the relative refractory phase schema.

I have tried to outline some of the evidence for the existence of a primary underlying factor in the variability of human response which is at once a protection against stereotypy and a condition of resystematization. If it were not for this underlying tendency all our lives might be spent in circles of narrow circumference and in the repetition of trivialities.

Neural patterns in the cord and brain-stem quickly reestablish their original sensitivity, and the consequent behavior patterns are quite permanent and characteristic of the indivdual. Even these, as we have seen, may change from the action of relative refractoriness. In labile or fluid neural systematizations like those of the cortex relatively slight decrements in the irritability of any link in the neural chain may produce profound modification of the behavior pattern or even apparent reversal of the mode of reaction.

If I may be permitted to point out in conclusion the main land-marks in our scientific excursion, I would emphasize the strategic importance of those phenomena whose accurate description under experimental conditions reveals something of the underlying processes, as, for instance, when outcrops of overt behavior may be arranged to serve as indicators of the underlying neural action.

We have shown how such overt acts as eye movements, knee-jerks, lid reactions and the like may reveal the momentary status of relatively stable neural systems and the interplay of various segmental levels of neural integration. We have shown further how a study of the sequence of such overt responses may be made to reveal far-reaching principles of integration like the refractory phase and the rebound. These are such fundamental conditions of normal life that psychology would be forced to invent them as hypotheses for the explanation of human experience and behavior even if experimentation had failed to disclose them.

THE BIRTH OF MODERN SCIENCE

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I

THE word science is capable of interpretation in so many different ways that it is desirable to define exactly what is meant by the term modern science. To many people the phrase suggests a Marconi, an Edison and the host of mechanical devices with which the application of scientific principles has deluged the world. Now while the writer has no intention of belittling the importance of applied science, in this historical sketch attention is directed to the work, not of the inventor but rather to that of the investigator who patiently and persistently seeks to learn something of the secrets of nature. Our modern scientist is the man who is more interested in a knowledge of the ultimate structure of gold than in its possession; who seeks not to build aeroplanes but to understand the laws of flight; who studies the starry heavens, not to cast horoscopes, but to learn something of the universe of which he is a part; who looks at the lilies of the field and wonders why they grow.

It is important to realize that a man of this type is no idle dreamer. He does not sit and gaze at the heavens seeking to evolve in his own mind the laws of the universe. On the contrary, he is a very practical person who tries to unlock the closed doors of nature by a well-defined method. In the first place he makes observations; he collects all the facts he can about the problem he is investigating. Not content with observations, he experiments to find additional facts. When a fair amount of accurate knowledge has been collected in this way, he tries to correlate the facts in what appears to be a reasonable explanation. In other words, he formulates a theory. Having formulated his theory, he proceeds to test it. If this theory is true, he says, then such and such should be the case. He, therefore, makes further experiments to see if his predictions are true. If they are not, that is, if the new facts thus brought to light do not fit in with his theory, it must either be revised or cast overboard altogether. His ultimate aim is truth. No matter how much he has prided himself on the beauty or on the correctness of his theory, a single fact which it fails to explain is sufficient ground for either altering it or casting it aside in favor of a new one.

Let me illustrate by a concrete example. Towards the end of the seventeenth century there were two outstanding theories concerning the nature of light. According to the first, a stream of extremely small particles is shot off from a luminous body. These corpuscles, as they were called, travel at a high speed through a vacuum and all transparent bodies, strike our eyes and cause the sensation of light. Supporters of the second theory stated that disturbances in the luminous body were the cause of trains of waves which were sent out in all directions. These waves, travelling through an invisible ether filling all space, impinge on our eyes and in this way the sensation of light results. *Now both these theories were attempts to explain existing facts.* It was known, for example, that light travels in straight lines; that a beam of light may be regularly reflected, and suffers refraction when passing from one medium into another. Neither of the theories, however, provided a completely satisfactory explanation of these and other facts.

Which was nearer the truth? This could not be decided until additional experimental facts had been obtained, and it was not until about the beginning of the nineteenth century that overwhelming evidence was given in favor of the wave theory. About the year 1800 Thomas Young showed experimentally that light added to light could give rise to darkness. Here was a fact which the corpuscular theory could not explain. It had either to be altered or overthrown. Later in the century it was shown, again by direct experiment, that light travels *more slowly* in water than in air. Now according to the corpuscular theory, the fact of refraction was explained on the supposition that light travels *more quickly* in a medium like water than in air. Here, then, was another direct contradiction to an experimental fact. The corpuscular theory, therefore, was given a knockout blow and at the beginning of the twentieth century the wave theory was almost universally accepted. It is still, however, only a theory. The last decade or two has seen many new discoveries in the world of physical science and some of these can not be satisfactorily explained by the wave theory, at least in its present form. The end is not yet and the search for truth goes on.

To sum up, modern science is born of a spirit of wonder and inquiry about the whole world of natural phenomena. Its keynote is found in the word, experiment; "Experiment and see" is the scientist's answer to innumerable questions. Its method is a combination of induction and deduction; theories are formed by inductive reasoning; they are tested by deduction. Scientists themselves must ever keep an open mind and at least aim to live up to the somewhat flattering tribute of Mr. H. G. Wells, who speaks of them as men who "think and work with an intensity, a breadth, boldness, patience, thoroughness and faithfulness—excepting only a few artists—which puts their work out of all comparison with any other human activity . . ."

How long has science been one of man's normal activities? When did modern science have its birth? These questions, like all others dealing with the beginnings of things, are not easy to answer. The accomplishments of the ancient Chaldean civilization are sufficient evidence that even in prehistoric days man had much knowledge of the physical world about him. Whether the men of those days had any real scientific outlook, even in the slightest degree, it is not possible to say. There is no doubt, however, that in the mental outlook of the Greek philosophers of the fifth and sixth centuries B. C., we find much that is in common with that of the twentieth century scientist. Thales, with his conception of water as the ultimate primary substance; Anaximenes, with his substitution of air for water and his theory of rarefactions and condensations; Herakleitos, with his idea of fire as the ultimate reality; Empedocles, with his four elements, earth, air, fire and water, were surely men seeking to explain natural phenomena. To Leukippos and Democritus atoms may have been more of an ultimate reality than they are to the twentieth century physicist, but these were men who undoubtedly were concerned about the structure of matter. Nor was experiment altogether absent in these early days. Empedocles, for example, is said to have proved the fallacy of the doctrine that space is "empty" by the use of a water clock. Water would not flow in, unless air went out. Air, therefore, he argued, is not empty space. Even before Empedocles, Pythagoras or the Pythagorean school was familiar with certain laws regarding musical intervals, laws which could scarcely be obtained without a certain amount of direct experimenting.

As we come nearer to the Christian era we are on more solid historical ground. The mass of extant literature

ascribed to the great Aristotle is ample evidence of the existence of the scientific spirit during the fourth century before Christ. The very names of many of the Aristotelian treatises—concerning physics, concerning the history of animals, concerning sound, concerning colors, concerning plants, concerning mechanics and so on—these very names show the interest of the philosophers of his time in scientific matters. In Aristotle's works we find a veritable mine of information on scientific subjects which many centuries later was to have such a tremendous effect on man's intellectual development. Aristotle, moreover, not only collected information but apparently also recognized the desirability of exact observation and of the necessity of a hypothesis "fitting the facts." "The phenomena are not yet sufficiently investigated. When they shall be, then one must trust more to observation than to speculation and *to the latter no further than it agrees with the phenomena.*" This is sound scientific doctrine, but Aristotle did not always practice what he preached. In one of his works he says: "That body is heavier than another, which in an equal bulk moves downward quicker." Bodies fall faster, the heavier they are. Now even a college freshman knows that this is not true and it is a very simple matter to prove the error experimentally. Apparently Aristotle and his school did not always use the experimental test.

Turning to Archimedes we find essentially a modern physicist. His discovery of the principle of the lever is a matter of common knowledge because of the saying attributed to him, "Give me a fulcrum on which to rest and I will move the earth." Almost equally well known is his work on hydrostatics and the principle which still goes by his name that bodies immersed in a liquid lose in weight an amount equal to the weight of the liquid displaced.

Of the accomplishments of Archimedes in mathematics and in engineering details can not be given, but there is no question that there is ample justification for the statement of Leibnitz, "whoever goes to the bottom of the works of Archimedes will admire the moderns less."

From even the briefest survey of Greek science, one can not omit the names of two other men, Hipparchus and Ptolemy.

Hipparchus, an astronomer who lived in the second century B. C., both in his outlook and in his methods was essentially a modern. Not content with accepting as final either the work or the theories of his predecessors, he made new and more accurate observations by means of which he showed the incorrectness of existing theories concerning the motions of heavenly bodies. Moreover, like a true modern, he worked out a new theory of the motion of the sun and the moon which was satisfactory in that it fitted the actual facts to the accuracy with which he was able to make observations. When we add that he discovered the astronomical phenomenon known as the precession of the equinoxes and laid the foundations of trigonometry, we must admit that Hipparchus is entitled to be ranked with the pioneers of modern science.

For over 250 years after Hipparchus no outstanding advances were made in the field of astronomy. In the second century of the Christian era, however, we encounter the work of Ptolemy, another outstanding name in the history of science. Of his varied activities one or two details only can be given. In optics he investigated experimentally the phenomenon of refraction, thus providing us with what one writer has described as "the oldest extant example of a collection of experimental measures in any other subject than astronomy." His most important work, however, was in the field of astronomy. Few ancient

scientific works are of more importance than his Syntaxis or the Almagest, as it is more frequently called, a treatise in which he presents a complete account of the astronomical facts, theories and instruments of his day. Of the tremendous importance of this treatise in medieval and renaissance days mention will be made later.

There is much evidence, therefore, that the Greeks laid the foundations of modern science. It is true that in many there was a confused blending of philosophy and science, a tendency to speculate rather than to experiment; it is equally true that in others we find a combination of the true scientific temper with the use of the experimental method. But Greek science declined and for many centuries, at least as far as European civilization is concerned, it was almost completely eclipsed. In spite of the amazing accomplishments of the Romans, their work in pure science is of little account. Their genius lay in other directions, along lines which were not favorable to the further development of science. Possibly it is unfair to cite the case of the Roman soldier who killed Archimedes as typical of the attitude of the soldier's race to abstract science, but at least it is suggestive of the difference between the Greeks and the Romans.

With the acceptance of Christianity by the Roman world, conditions became less and less favorable for the development of science. It was perhaps not unnatural that the early Christians should view with disfavor the intellectual activities of a people whose morals were not always of the best and whose outlook in many matters was frequently paganistic. In any case we find a twofold attitude displayed towards scientific matters. There was first of all a kind of contempt for such questions, a feeling that matters concerning the soul's salvation were so urgent that after all such studies were of little moment. "What concern is it to me," says St. Augustine, "whether the heavens enclose the earth in the middle of the world or overhang it on either side?" Basil of Caesarea states "it a matter of no interest to us whether the earth is a sphere or a cylinder or a disk or concave in the middle like a fan." But interest in the world about us is a natural instinct, and of this there is ample evidence in the other attitude of the early church fathers towards science. In the scriptures can be found the solution of many scientific questions and disputes. Why go to pagan philosophers when we have the law and the prophets? By way of illustration, consider an argument advanced in the sixth century by Procopius of Gaza against the possible existence of men on the antipodes. Such a thing is out of the question, he argued, because it would mean that our Lord must have gone there and died a second time. In support of the same position St. Augustine argued that such men could not exist because "Scripture speaks of no such descendants of Adam."

Gradually, therefore, the church developed a sacred pseudoscientific system of the earth and of man's place in the universe. Utterly unscientific in its formulation, it was supported with the tremendous authority of the church of the middle ages, and, as we shall see later, became a stumbling block in the face of which real scientific progress was a very difficult matter.

The downfall of the decadent Roman empire before the invasion of uncultured barbarians was a second powerful factor in bringing about a condition of affairs totally unfavorable to scientific advance. Much of the ancient learning was lost and civilization sank to the low ebb implied in the name Dark Ages. Throughout this period knowledge and intellectual interests were in the hands of the clergy; political life was one of wars and readjustment, while, to quote Professor G. B. Adams, to many people "the dark terrors of the world of lost

souls, which they crudely but vividly pictured to their minds as horrible physical torments, pressed upon them with a reality almost as immediate as that of the world in which they were really living." In such an atmosphere the spirit of modern science did not exist.

II

Only a brief reference can be made to the conditions which gradually created an atmosphere favorable for the rebirth of the true scientific spirit. During the Dark Ages there was much activity along mathematical and astronomical lines among the Hindus and Mohammedans of the far east. While they seem to have made but few new contributions to science, Greek ideas were preserved as well as translations of Greek manuscripts. Now, as is well known, during the ninth and tenth centuries Mohammedanism spread into Europe and a remarkable Moorish civilization arose in Spain. Almost palatial in its splendor, strangely enough it was marked by an intense interest in learning, particularly on the scientific side. To quote Hume:

> Cordova then became the center of scientific investigation. Medicine and surgery especially were pursued with intense diligence and success, and veterinary surgery may be said to have crystallized into a science. Botany and pharmacy also had their famous professors, and astronomy was studied and taught as it had never been before; algebra and arithmetic were applied to practical uses, the mariner's compass was invented, and science as applied to the arts and manufactures made the products of Moslem Spain—the fine leather, the arms, the fabrics, and the metal work—esteemed throughout the world. . . .

Before this remarkable era in Spain had come to an end, a new ferment was at work in Europe. Contact with the east as a result of the Crusades and gradually developing commerce had enlarged the horizon of many men and stimulated their imaginations. New impulses began to stir, minds became more active. The more settled state of Europe permitted scholars to go afield in search of knowledge and of manuscripts, visits even from England to Spanish centers of learning being not unknown. Indeed, in the twelfth century there was such a revival of learning that, according to so eminent an historian as C. H. Haskins, we have to do with a true renaissance. While this movement centers largely in numerous translations of Greek manuscripts into Latin, it is by no means unrelated to the theme of this article. The translators of this period were interested not so much in the humanistic side of the classical writers as in their scientific and philosophic knowledge. And so we find Latin translations of the works of such men as Ptolemy, Euclid, Galen, Hippocrates and Aristotle. Aristotle's logic, it is true, had been known and indeed of great importance throughout the Dark Ages, but in the twelfth century his scientific works gradually made their appearance. Translations of Ptolemy's Almagest, with its thorough summary of Greek astronomy, came to light both from Arabic sources about 1175, and somewhat earlier, from Greek sources through Sicilian channels. In the twelfth and thirteenth centuries, therefore, scholars had at their disposal numerous Greek scientific works. What use did they make of them? Is there any evidence that the interrupted stream of scientific activity once more began to flow along Hellenistic channels?

To that question we may answer both "yes" and "no"; yes, because there is undoubtedly much evidence of the existence of the true experimental scientific method during this period; no, because influences opposed to the rebirth of the spirit of the Greeks in some respects increased rather than decreased. The positive evidence will be given by a glance at the work of two outstanding figures of the thirteenth century. In the Norman kingdom of Sicily, where Latin, Greek and Arabic influences came together, there ruled at this time a remarkable per-

sonality, King Frederick the Second. The head of a court which patronized learning, he himself had an active scientific mind. That he was also an experimentalist there is some evidence in certain tales which are related of him. Wishing, for example, to know the comparative effects of sleep and of exercise on digestion, he gave to each of two men a hearty dinner. After their repast, one was sent hunting, the other ordered to take a sleep. Later, the two were put to death and an analysis made to see whether rest or exercise were the better aid to digestion. Another story of a less scientific nature is to the effect that certain children were brought up in silence in order to find out "whether they would speak Hebrew, which was the first language, or Greek or Latin or Arabic or at least the language of their parents; but he labored in vain, for the children all died."

His real scientific work, however, lay in the field of natural history. A fondness for animals, combined probably with a love of show, led him to bring together a veritable menagerie of "elephants, dromedaries, camels, panthers, gerfalcons, lions, leopards, white falcons and bearded owls." But it was by no means for show alone that he used his animals. A treatise on falcony, "De arte venandi cum avibus," is ample evidence of an exact scientific study of the habits of such birds obtained by accurate observation on his own part, combined with a systematic investigation of the knowledge of others. Moreover, while familiar with and to some extent following the works of Aristotle on natural history, he did not hesitate to criticize the great master, even accusing him of at times relying too much on hearsay. That Frederick's interest in scientific matters was not limited to natural science, one illustration must suffice. Following a custom to which he seems to have been addicted, he at one time sent to the sultan of Egypt the following optical questions for solutions by Moslem scholars: (1) Why do objects partly covered with water appear bent? (2) Why does Canopus appear bigger when near the horizon, whereas the absence of moisture in the southern deserts precludes moisture as an explanation? (3) What is the cause of the illusion of spots before the eyes?

A much more important and almost equally dramatic figure is found in the person of Roger Bacon. Born in England at the beginning of the thirteenth century, he seems to have spent his early manhood studying at Oxford. At Paris he continued his studies, taking the dialectic training of his day and ultimately receiving the doctor's degree. Subsequent work at Oxford rendered him suspect to the members of the Franciscan order to which he had attached himself, and once more he returned to Paris, this time more or less under surveillance. A few years later the interest of a liberal-minded pope gave him an opportunity to write his famous works and so to hand down to posterity a detailed account of his accomplishments. A later treatise in which he in scathing terms denounced the evils of the church and society of his day proved too much for the superiors of his community, and a period of fifteen years in prison put an end to further writing. (When an old man he was released, but it was then too late for him to do any further work of importance.)

Now, what did this man do and why is he so outstanding a figure in the history of science? Note what he himself has to say:

> For now I have laboured from my youth in the sciences and languages, and for the furtherance of study, getting together much that is useful. I sought the friendship of all wise men among the Latins, and caused youth to be instructed in languages, and geometric figures, in numbers and tables and instruments, and many needful matters. I examined everything useful to the purpose, and I know how to proceed, and with what means, and what are the

impediments; but I cannot go on for lack of the funds which are needed. Through the twenty years in which I laboured, especially in the study of wisdom, careless of the crowd's opinion, I spent more than two thousand pounds in these pursuits on occult books and various experiments, and languages and instruments, and tables and other things.

Again:

The study of wisdom may always increase in this life, because nothing is perfect in human discoveries. Therefore, we later men ought to supplement the defects of the ancients, since we have entered into their labours through which, unless we are asses, we may be incited to improve upon them. It is most wretched always to be using what has been attained and never reach further for one's self. . . . In every act of life, or business, or study, these three vast arguments are used for the same conclusions: this was the way of our ancestors, this is the custom, this is the common view: therefore should be held.

Surely we have to do with a man who, like the modern scientist, is not willing to accept as final the conclusions of his predecessors, who refuses to accept the argument of mere tradition, who realizes that new knowledge may be obtained by observation and experiment.

Turning to his scientific writings, we find them treating of a vast range of subjects, into the details of which it is not possible to go. In any case, what the writer would like to emphasize is not so much his actual scientific accomplishments as his insistence on the necessity of the experimental method. To him the crowning test of the truth of all knowledge lay in "experimentia." Let him again speak for himself:

There are two modes of arriving at knowledge, to wit, argument and *experimentum*. Argument draws a conclusion and forces us to concede it, but does not make it certain or remove doubt, so that the mind may rest in the perception of truth, unless the mind find truth by way of experience.

Again:

But beyond these sciences is one more perfect than all, which all serve, and which in a wonderful way certifies them all: this is called the experimental science, which neglects arguments, since they do not make certain, however strong they may be, unless at the same time there is present the *experientia* of the conclusion. Experimental science teaches *experiri*, that is, to test by observation or experiment, the lofty conclusions of all sciences.

Finally:

When Aristotle speaks of knowledge of the cause as a higher kind of knowledge than that gained by experience, he is speaking of mere empiric knowledge of a fact; I am speaking of experimental knowledge. There are numerous beliefs commonly held in the absence of experiment, and wholly false, such as that adamant can be broken by goats' blood, that a vessel of hot water freezes more rapidly than one of cold and so on.

Now two examples do not establish a case, but they do serve to illustrate the point which might be amplified, that in the thirteenth century there were unmistakable signs of a rebirth in science. On the other hand, influences opposed to the spirit of a free and an experimental inquiry into natural phenomena were not lessened by the new knowledge. In Roger Bacon himself, we see an example of one such influence. In spite of all that has been said concerning his position as a scientist, in one respect he is no exception to the philosopher-theologians of his day. To him, as to them, theology was the queen of the sciences; all other branches were her handmaidens. It must be remembered that throughout the medieval ages learning was for the most part in the hands of the theologians. While many of these, particularly in the latter half of this period, were extremely able men, and some not without an interest in natural phenomena, the keynote of all their studies was theology; salvation, not science, was their primary concern. The result was often a strange mixture. Here is one example of a scientific question and its theological answer: "Why is the sun so red in the evening? Because he looketh down upon hell."

It is in scholasticism, however, that we find the strongest of all the influences opposed to the development of the scientific spirit. Scholasticism, strangely enough, was one of the results of the intellectual stimulus which came to Europe at this time. A wealth of new material, in the form of bad Latin translations, is brought to the attention of men whose wits had been sharpened by the prevalent training in logic and in dialectic, whose interests were predominately theological, whose minds were stimulated by the economic and political changes affecting the Europe of their day. It is not surprising, therefore, that such men, seizing on the new but often inaccurate material, endeavored to incorporate it in their theological system. With Aristotle as a theologian they had long been familiar; of Aristotle, the natural philosopher, they were at first somewhat afraid, and we read of the prohibition of some of his works at the University of Paris. Soon, however, the ban was removed, and it was not long until the able minds of the thirteenth century had gladly accepted a somewhat perverted Aristotle and had created what G. B. Adams has described as "a gigantic system of organized knowledge, in so far as there was knowledge, in which almost every conceivable idea had its place, and which exercised a most tyrannous sway over all mental activity, because it was so intimately bound up with an infallible system of theology which every mind was obliged to accept under peril of eternal penalties."

Now it need scarcely be added that the spirit of such a system, dominated as it was by the double authority of an infallible theology and a misrepresented Aristotle, was almost fatal to scientific progress. It is true that the early schoolmen included in their number some of the keenest intellects the world has known; it is equally true that their scholastic philosophy developed into the most futile speculations. For example, we read of questions such as these: "Could God make two hills without an intervening valley?" "Could God make a stick a yard long which had not two ends to it?" "What happens when a mouse eats the consecrated host?" Had later scholastics done nothing but "spin laborious webs of learning out of no great quantity of matter and infinite agitation of wit"—to quote Francis Bacon—we might pass by with nothing but a smile. But such was not the case. The syllogism, for example, was applied to scientific problems as well as to philosophical. A good illustration of its use is found in the following argument concerning the antipodes, used by a Spanish theologian in the fifteenth century. "The apostles were commanded to go into all the world and preach the gospel to every creature; they did not go to any such part of the world as the antipodes; they did not preach to any creatures there; ergo, no antipodes exist."

While the thirteenth century, therefore, undoubtedly gave evidence of the dawn of the twilight of a better day, full daylight was not to come until many storm clouds had passed. In the imprisonment of Roger Bacon for "certain suspected novelties"—as his accusers put it—we see a forerunner of the storm which nearly three centuries later was to break on the head of Galileo.

III

In the second half of the fourteenth century, we have the beginning of the period frequently assigned to the Renaissance. With the pioneer work of Petrarch, who was not a scientist, this is not the place to deal. Indirectly, however, the movement with the beginning of which he is so closely identified was of tremendous importance to the advancement of science. Petrarch, in seeking to recover the spirit of the ancient classical world, in applying to historical documents the modern scientific method, in his refusal to accept Aristotle's au-

thority as final and in his ridicule of the universities, the citadels of scholasticism, did yeoman service to the cause of science. And yet neither in the fourteenth nor in the fifteenth nor even in the sixteenth centuries was there any great outburst of what might be called modern science. There was progress, to be sure, but advances were so slow that it is worth while to consider some of the causes for the apparent lag of science behind other fields. How was it that during a period in which there was such a remarkable orientation of men's minds, the rebirth of modern science was so slow?

Some of the causes have already been indicated; a few others may be briefly mentioned. In the first place, during the revival of learning, scholars were engaged in recovering ancient manuscripts; their joy to some extent was that of the collector; their interest was in the glory of a past civilization as much as in the world about them. The translations, moreover, were frequently faulty; even Petrarch was not a Greek scholar and it was not until after his day that Latin translations were replaced by original and more accurate Greek manuscripts. There was a tendency to substitute the commentary on scientific works for a direct appeal to nature. Even granted a genuine interest in science on the part of many scholars, time was necessary for the recovery and the assimilation of the work of the Greeks. Then, too, as some one has said, it is quite possible to read the classics without becoming forthwith Hellenistic in one's attitude of mind—a remark, by the way, as applicable to the twentieth century as to the fourteenth and fifteenth. A striking example of this is found in the fact that as the intellectual class gradually included many who were by no means theologians, Aristotle became as great an authority with the skeptics as with the scholastics. Aristotle, says Harvey as late as the seventeenth century, "has always such weight with me that I never think of differing from him inconsiderately."

In the next place advances which can only be made by the method of experiment and of observation are necessarily slow. Even in the twentieth century, with its wealth of aids to investigation, years may elapse before accumulated facts are correlated in some underlying principles. How much more slow, then, in days when the telescope and the microscope had yet to be invented; when there were no thermometers, no air pumps; when the pendulum clock had not come into existence; when for part of the time, there was no printing press. A great deal of preparatory work was a necessary condition for any striking scientific advances. Telescopes could not be invented without a previous study of lenses; for many problems in subjects like astronomy improved mathematical processes were necessary; and in the same subject, the laws governing the movements of heavenly bodies could not be understood until Galileo and his contemporaries had laid the foundations of the science of mechanics.

Finally, there was much in what we might call the zeitgeist of these centuries which operated against the development of a pure science. Few men can rise entirely above the common prejudices of their day and generation, and throughout the Renaissance period many things now scoffed at by science were accepted without question. A good illustration is found in the following quotation from Taylor's "Thought and Expression in the Sixteenth Century":

> George Agricola in 1556 published his *De re metallica*, an excellent and complete treatise upon everything connected with the mining and metallurgy of the time in Germany. It treats of the origin of veins and ore deposits, and discredits the use of divining-rods to discover veins of metal. But it recognizes devils, along with bad air and venomous ants, as among the pests encountered in mines.

Here is another example in the field of medicine, "At Florence, the very heart of classical enlightenment, in the year 1494, when Lorenzo de' Medici lay on his death bed, the last medicine given him was a draught of pulverized jewels." Still another is found in the case of the famous surgeon, Ambrose Parée, who, in spite of his deserved rank as a pioneer of modern surgery, believed in sorcery as a possible cause of wounds. Numerous other illustrations could be given to show that few of even the most advanced scientists of this period were able to throw overboard completely belief in supernatural agencies. This is perhaps not surprising when we reflect that in the present day we are not entirely free from the same attitude. It is not difficult to find those who can not be persuaded to walk under a ladder, or those who, when the table salt spills, immediately throw some over their left shoulder. People can still be found who carry horse chestnuts on their persons as a cure for rheumatism, while only a few months ago the writer picked up a newspaper with a full page horoscope for the year of our Lord 1925.

Belief in magic, charms and supernatural agencies must not be confused with the practices of alchemy and astrology, two semi-scientific pursuits characteristic both of the latter middle ages and the Renaissance. In both of these we have at once a help and a hindrance to the cause of pure science. In spite of the atmosphere of secrecy, of nonsensical symbolism, at times even of fraud and deception which frequently pervaded the work of the alchemists, their number included many who were undoubtedly the founders of modern chemistry. If no great principles were discovered, alchemy was responsible for many chemical methods and processes which time does not permit to discuss.

What alchemy was to chemistry, astrology was to astronomy. The influence of stars and planets on the fortunes of men could not be discovered without accurate knowledge of the positions and movements of the heavenly bodies. Astrology, therefore, was a stimulus to the cause of observational astronomy and herein is possibly one reason why so much of the pioneer work in science was in that field. On the other hand, the casting of horoscopes is not exactly consistent with the aims and methods of modern science and such pursuits did little to hasten its arrival. If, however, progress during the Renaissance was slow, it was real, and a brief reference will now be made to the work of a few of the outstanding pioneers of that period.

IV

The first of these is Leonardo da Vinci, painter, botanist, biologist, physiologist, anatomist, physicist and engineer. In this article our interest is not so much in his actual achievements as in his attitude towards the world of nature. He was the very antithesis of those who would deduce scientific principles from faulty premises. For him, *esperienza,* a combination of observation, experiment and investigation, was the only method of arriving at an understanding of the phenomena of nature. "Those sciences are vain and full of errors," he says, "which are not born of esperienza, mother of all certitude . . ." "I will make esperienza before I proceed, because my intention is first to set forth the facts and then demonstrate by reason why such esperienza is constrained to work in such fashion, and this is the true rule to be followed by the investigators of natural phenomena." Not only did Leonardo both preach and practice to an amazing degree esperienza, but at the same time he emphasized the importance of the *quantitative* side of physical investigation. "There is no certitude where some one of the mathematical sciences can not be applied." As an example we may cite

Leonardo's interest in flying machines and in the flight of birds. Observation alone was not sufficient for a knowledge of the laws of flight. "The bird," he says, "is a machine working through mathematical law."

And so this marvelous man in a highly scientific fashion examined experimentally almost everything which came into his ken. For exact lines in painting a knowledge of anatomy is desirable. Nothing will do for Leonardo except a direct study by dissection of the human body, and that, too, in defiance of the canons of the church. He sees in the moon an object for investigation and in his notes we find the suggestion, "construct glasses to see the moon magnified" —this, mark you, over one hundred years before the invention of the telescope. To turn from the schoolmen to Leonardo da Vinci is like going out into the fresh air from a hot and stuffy room.

From Leonardo we turn to Copernicus, the first of a series of five men whose work brings us into the full daylight of modern physical science. Nicolaus Copernicus, a native of Poland, whose studies in medicine, astronomy, mathematics and theology had taken him successively to Cracow, Vienna, Bologna, Padua, Ferrara and Rome, eventually was made canon of Frauenberg, where he spent the last thirty years of his life. There he found time not only for his duties as priest but also for those of doctor and astronomer. Although neither great as an experimenter nor a giant in intellect, he occupies a place in the front rank of the pioneers of science. As every one knows he came to the conclusion that the sun, not the earth, was the center of the solar system, that we have to deal with a heliocentric not a geocentric system. The idea was not an original one—"I searched among the books of the philosophers," he says, "until I found that some of them conceived the earth to move"—but it was certainly revolutionary. Just think for a moment what it meant. The schoolmen and all later theologians had set the seal of an infallible authority on the Ptolemaic system. Theology and science had combined to construct a soul-satisfying scheme which it became heresy to question. Surrounding the earth enthroned in the center of the universe were nine rotating spheres, seven for each of the moon, mercury, venus, sun, mars, jupiter, saturn, the eighth for the fixed stars, the ninth the crystalline sphere—the primum mobile. Beyond was the tenth heaven, the immovable empyrean, wherein was the throne of the Almighty. This system, moreover, as elaborated by Ptolemy, was able to account at least roughly for the observed motion of the planets, to predict eclipses and to provide necessary astronomical data for the church calendars. And in the face of all this a quiet studious monk dares to suggest that the earth with man on it be moved from its all-important central position. His reasons are based on a thoroughly scientific method. As he explains in the preface to his famous book "De Revolutionibus Orbium Celestium," dissatisfaction with the "traditional mathematical doctrine concerning the paths of the heavenly bodies" led him to adopt an idea suggested many centuries before, and, as he puts it, "to try whether on the theory of the motion of the earth more satisfactory explanations than heretofore might not be found for the movements of the heavenly bodies." This theory he put to the test with the conclusion "that if the movements of the other planets were referred to the motion of the earth in its orbit and reckoned according to the revolution of each star, not only could their observed phenomena be logically explained, but also the succession of the stars, and their size, and all their orbits and the heavens themselves would present such a harmonious order that no single part could be changed without disarranging the others and the whole uni-

verse." It was as if the mantle of Hipparchus had fallen on the shoulders of Copernicus. The application of the modern scientific method had led him to the formulation of a new and revolutionary theory which better fitted the facts. And what were the consequences? Strangely enough, there was apparently no great immediate outburst of opposition. To be sure there was opposition, as will be sufficiently evident from the following comment of Luther: "The fool will overturn the whole art of astronomy. But as holy writ declares, Joshua commanded the sun to stand still and not the earth." But there was no immediate conflict for reasons some of which are not hard to find. Copernicus, who for some years had quietly communicated his ideas to interested people, lived only long enough to see the completion of his famous book. He was unaware that a false paragraph had been added to his preface by a Lutheran friend to the effect that the theory advanced was only a hypothesis, a kind of picture puzzle solution of this big astronomical problem, but by no means a claim to be the actual truth. This spurious preface, combined with the friendship of a cardinal of the church, doubtless did much to disarm criticism. His case, moreover, was not yet strong enough. More accurate observations and a knowledge of the mechanics of moving bodies were necessary to make the case for the Copernican theory so strong that an alternative was not possible.

Accurate observations were provided by Tycho Brahe, a native of Denmark and one of the most remarkable astronomers who has ever lived. A man who did not accept the Copernican theory, who saw in the conjunction of Jupiter and Saturn a cause for the great plague, who all his life dabbled in alchemy and astrology—such a man seems scarcely worthy to be ranked with Copernicus. And yet his experimental work in point of accuracy is so much in advance of any of his predecessors that he well deserves the name of the first Astronomer Royal. Private means, combined with praiseworthy aid from Frederick II of Denmark, enabled him to construct the castle of Uranibourg, a palatial observatory where for over twenty years with improved instruments Tycho corrected and extended existing astronomical observations to an accuracy hitherto undreamed of. So renowned was this man and his observatory that we read of an eight-day visit to Uranibourg by James I of England on the occasion of his marriage with Anne of Denmark.

After the death of Frederick, evil days fell upon Tycho and we read no more of his famous castle. In 1599, however, he was invited by the emperor of Bohemia to settle in Prague, where he spent the remaining two years of his life. In this brief sketch these two years would not be mentioned at all were it not for one outstanding event. During that time a young German by the name of Kepler came to work under Tycho Brahe. Now this young man, although no great experimenter, had a passion for trying to get beneath facts. Is there any law governing the distances of the various planets from the sun? Is there any reason why there should be only six? How are the periodic times related to their corresponding distances? Questions such as these had been exercising the mind of Kepler before he came to work with Tycho, and to some of them he had already given tentative answers in a book published in 1597. To test his theories, however, more accurate observations were necessary, and so he went to Tycho Brahe. A man with a passion for underlying principles, equipped with keen scientific imagination and mathematical ability, avails himself of the careful work of a brilliant experimenter. The result is not surprising. After years of patient toiling, of many hypotheses tried and cast aside because they did not fit the facts, the true law is discovered. It

is very brief, and very simple—planets move in ellipses with the sun in one focus. It is difficult for those who have had little training in physical science to appreciate the full beauty of this sweeping generalization which fitted the facts to the high order of accuracy attained by Tycho Brahe. One very important point, however, can readily be appreciated, and that lies in the substitution of the ellipse for the circle. Aristotle had taught, and for centuries it had been accepted, that the true and perfect motion was circular. Now a simple circular motion does not explain the motion of the planets and both in the Ptolemaic system and the Copernican, combinations of circles known as epicycles—wheels within wheels, so to speak—had been used. Copernicus had reduced the number of epicycles from 79 to 34, and in other respects wrought much simplification. Kepler, however, in his discovery of the simple elliptical law, at one stroke did away with the whole system of epicycles and at the same time struck another fatal blow at the authority of Aristotle. It is little wonder that his joy over this and other discoveries is unbounded. "Nothing holds me," he states after solving a problem which had proved too much for Alexandrian astronomers, "nothing holds me, I will indulge in my fury; I will triumph over mankind by the honest confession that I have stolen the golden vases of the Egyptians to build up a tabernacle for my God, far away from the confines of Egypt."

Just about the time Kepler was making his brilliant investigations, an Italian contemporary, Galileo Galilei, a native of Pisa, was startling the world with results obtained by looking at the heavens, for the first time, through a telescope. Galileo began his career with the double advantage of a liberal education, including classics and mathematics, and of a home influence which stood for open inquiry, untrammeled by the authority of tradition. Although in early years destined for business, a wise father sent him to the university to study medicine. But he was one of nature's born investigators, and it was not long before he found the natural outlet for his talents in the study of physical science. Seldom has such study brought so rich a reward. Even when a lad of eighteen, Galileo's genius for experimental investigation is evident in his observation of the swings of the great lamp in the Cathedral of Pisa, and consequent discovery of the isochronism of the pendulum, a law on which the construction of all pendulum clocks is based. This marked the beginning of a career in which the modern scientific method of observation and experiment, of induction followed by deduction and experimental verification, was constantly in evidence. Do bodies fall the faster, as Aristotle maintained, the heavier they are? Experiment and see, says Galileo, and so he climbs to the top of the famous leaning tower of Pisa, drops simultaneously a one pound mass and a hundred pound mass. They strike the ground together, and thus in the course of a few minutes the learned gentlemen who constitute the faculty of the University of Pisa receive a convincing demonstration of the fallacy of the 2,000 year old maxim of Aristotle's. Such experiments are followed up by careful investigations of the laws of moving bodies, laws with which all students of mechanics nowadays must be familiar. In other branches of physics the same sound methods are applied; in thermometry, in hydrostatics, in acoustics, in optics—whatever the field, it is approached in the same way. The modern physicist, in reading Galileo's writings, feels that spiritual kinship which exists between men whose aims and methods are the same.

But it is in the field of astronomy that the startling discoveries are made. Galileo, hearing of the existence in Holland of an instrument which magnifies distant objects, constructs a telescope. A new world is the result. "Many noblemen and senators, though of advanced age, mounted to the top of one of the highest towers to watch the ships which were visible through my glass two hours before they were seen entering the harbor, for it makes a thing fifty miles off as near and as clear as if it were only five." The telescope is directed to the heavens and a wealth of new knowledge is available for the mind of man. There are hills and valleys on the moon; not only are there spots on the sun, but they move; Saturn has rings; Jupiter has three or four satellites which revolve about her, and Venus exhibits phases just like the moon. Predictions of Copernicus are verified and for all who have eyes to see there is ample evidence of the truth of his view of the solar system. But there are those who, having eyes, see not, those who harden their hearts even in the face of cold facts, and these were not wanting in Galileo's time. His discoveries were too much for the reactionaries. Some refused to look through the telescope; others said that, while it might be all right for terrestrial objects, it could not be trusted for heavenly. Some tried to dispose of the matter by foolish argument. And the matter did not end even there. The Inquisition took Galileo in hand. It will be noted that as the truth of the Copernican theory became more and more evident to men with open minds, the opposition of the reactionaries increased. Copernicus' famous book was not immediately placed on the prohibited list; a book of Kepler's, giving a clear statement of the theory, was, however, at once put under the ban, while for Galileo was reserved the distinction of being persecuted. After a period, the details of which it is as well to omit, Galileo, a broken man of seventy years, finally recanted. "I abjure, curse and detest the said heresies and errors"—this from the lips of a man who had once said "It is not in the power of any creature to make them to be true or false or otherwise than of their own nature and in fact they are."

But no one knew better than Galileo that truth can not ultimately be suppressed. The apparent victory of the reactionaries might delay but it could not stop the forward march of science. All along the line the dead weight of authority and tradition was being cast aside. In anatomy Vesalius had broken with those who were satisfied with Galen and Hippocrates; in zoology and botany, Gesner had become the pioneer of the moderns; in 1600 Gilbert had published an account of his investigations in electricity and magnetism, and in 1628 Harvey announced his discovery of the circulation of the blood. Reactionary influences continued, indeed they are still with us, but they could not destroy the new spirit which was at work in the world. In the year in which Galileo died, Isaac Newton was born. With that great genius we have left the Renaissance far behind and found ourselves in the full daylight of modern science.

THE FRIENDSHIP OF TWO OLD-TIME NATURALISTS

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"THOREAU would be a splendid entomologist if he had not been spoiled by Emerson." This remark was once made by Dr. Thaddeus William Harris concerning one of his most valued personal friends, Henry David Thoreau. Perhaps the words were spoken whimsically or in jest, but nevertheless it is probable that they contain a germ of truthfulness regarding the estimate by Dr. Harris of his friend.

There are few of the present-day entomological fraternity who possess sufficient antiquarian tastes to take the time or trouble for anything like a serious consideration of the lives of the individuals who composed the historical background of economic entomology in this country. These few, no doubt, have realized somewhat vaguely that Harris and Thoreau were contemporaries. Yet scarcely any appear to have appreciated the fact that these men were close personal friends and that this relationship in some degree was of so unique a character as to be worthy of present-day attention.

Doubtless it will possess a value in these hectic times of large appropriations, of extensive personnel and of extreme specialization to review briefly and ponder some of the existing records which stress the more outstanding characteristics that combined to make up the splendid comradeship which existed between these two old-time naturalists. It may be helpful in these strenuous days of graphs and charts to endeavor to visualize in some degree their serene lives and philosophy, their placid methods of study, all unhaunted by present-day mathematical formulae or logarithmic tables, and their broad outlook upon, and cosmopolitan interest in, all nature's phenomena. A consideration of their lives and achievements may give one a feeling akin to sympathy for some of those who make a plea that there be, in some degree, a renaissance from the present-day hair-splitting specialization to some of the ideals of the old-time naturalist.

During a considerable portion of the active working period of the life of Dr. Harris there probably were not a half dozen people in this entire country who were sufficiently interested in the study of entomology to be considered worthy of the name of entomologist. Any adequate consideration of him, therefore, during that time necessarily would include a history of American entomology for the same period, and this fact gives especial interest to his career and to the friendships he formed with Thoreau, Agassiz and others of his time.

Born in Dorchester, Massachusetts, November 12, 1795, Harris was twenty-two years older than his friend Thoreau. The elder Harris, his father, was a librarian at Harvard, a Congregational minister, a learned antiquarian and author of a number of religious and scientific works, among which was an elaborate work on the "Natural History of the Bible." It seems that his mother also was more or less interested in matters entomological, because for some years she was diligent in rearing silkworms. The home environment of the

youth, therefore, formed a fitting background for subsequent scientific work, and it is known that, true to form, the lad early began to make a permanent collection of insects. He was graduated from Harvard in 1815, devoted himself to the study of medicine, took his medical degree in 1820, married shortly thereafter and then began medical practice at Milton, Massachusetts.

It does not appear that he ever became really attached to his profession or attained a really lucrative medical practice, and eventually his pecuniary anxieties became so great that, after considerable strenuous casting about, he secured an appointment in 1831 as librarian at Harvard College. This position he held during the remainder of his life. The daily routine of this work was of a character to render it congenial to one having such methodical and accurate habits of thought as Dr. Harris. The library was very small at the inception of his period of services, and limited funds gave little subsequent opportunity for its increase, especially along scientific lines, although it grew from thirty thousand to sixty-four thousand volumes during his lifetime.

For some years he was also in charge of the annual course of lectures on "natural history," with special lectures on botany. Eventually he formed a private class in entomology for the benefit of the very few who cared to attend it. According to the recollections of one of his students, Dr. Samuel H. Scudder,[1] these classes must have been very delightful, though progress was slow, and the class did not go beyond the Coleoptera. "Dr. Harris," he says, "was so simple and eager, his tall, spare form and thin face took on such a glow and freshness as he dwelt so lovingly on antennae and tarsi, and as he so fondly handled his little insect-martyrs, that it was enough to make one love the study for life!"

It was only by vast labor and pains during his spare time that Dr. Harris was able to accumulate for his study a working collection of specimens and an adequate library for his researches. The resources of the college library and his own collection were pitifully inadequate for use in a really serious study of entomology, and it therefore became necessary for him to prepare from borrowed material an extended series of manuscript indexes of a large number of the principal systematic works on Lepidoptera, Coleoptera and other orders, as well as general works on entomology. These manuscript books eventually became extensive in number and are now in the archives of the Boston Society of Natural History. "So beautifully executed is all this laborious work," says Scudder, "that it is as easily accessible as print, though the earlier sheets are yellow and torn." Since all this work was gratuitous and entirely independent of his regular duties as librarian and instructor, one can well imagine that a man of meager pecuniary means with a family of twelve children to share his time and resources must have had very little time or money for the pursuit of such a hobby, no matter how engrossing or fascinating such an avocation was certain to be to a person of his training and tastes.

In 1831 he prepared a catalogue of insects, which was published as an appendix to Hitchcock's "Massachusetts Geological Report." Later he was appointed by the state of Massachusetts a member of a commission to make a more thorough geological and botanical survey of the state. It was while he was performing this work that he brought together his noted classic, "Report on Insects Injurious to Vegetation." This report was first published in full in 1841, the section on beetles previously

[1] Scudder, S. H. (Ed.) "Entomological Correspondence of Thaddeus William Harris," Boston, Bost. Soc. of Nat. Hist. 1869.

having appeared in 1838. In 1842 it was reprinted as "treatise" instead of "report" and again reprinted in a revised form in 1852. The entire sum received from the state for this labor was $175. The work was reprinted by the state after his death in its present form, with wood engravings so beautifully executed as to mark an epoch in that art. Says Dr. L. O. Howard[2] in 1899:

> The practical value of Dr. Harris's work has been vast. His scientific reputation has steadily grown. His book is to-day as valuable as it was when first written, more than fifty years ago. On entering any entomological workshop in the land the first book that will catch the eye upon the desk is a well worn copy of the "Treatise upon insects injurious to vegetation."

In studying the writings of Dr. Harris, it will be found that his generalizations have stood well the test of subsequent and more elaborate research. It has been said of Harris that his "insight into nature and the relations of affinity, although they might be based upon a meager series of natural objects, was truly enviable." It seems, however, a great loss to the advancement of knowledge that the maturity of Dr. Harris's powers should have been diverted for so much of the time from his zoological studies and that such a large part of his time should have been, as it were, wasted on routine drudgery which might have been performed by some mediocre helpers. Yet, with all its disappointments and misfits, his life could hardly be regarded as unhappy. If he could not be wholly a naturalist, yet there is no doubt that he found enjoyment in being a librarian. In view of his inheritance and his training he seemed to be born with a librarian's interest in alcoves and pamphlets and endless genealogies. It is known that he kept his official records with exquisite accuracy and described his methods on occasions to fellow-librarians as sympathetically and as lovingly as if he were describing a most delicate chrysalis.

Although the general health of Dr. Harris was good during the greater part of his life, yet the habitual overwork to which he was subjected led to occasional nervous exhaustion and to severe headaches. During his last years he was the victim of heart disease and pleurisy, with other complications. His last illness began in November, 1855, and he died of heart disease on January 16, 1856, in his sixty-first year.

The impossibility of attempting to compress within a few brief paragraphs an adequate outline of any human life is realized with an especial feeling of despair in the case of such a strongly marked individuality as was that of Thoreau. Born near Concord, Massachusetts, July 12, 1817, of American parentage descended from Scotch and French ancestry, Thoreau spent his childhood and youth in poverty, though in a pastoral country amid scenes of placid beauty. In this environment he early became passionately devoted to a study of the varying aspects of nature and to the delights of solitude, and when only twelve years of age he began to make collections for Agassiz, who had just then arrived in America. During his entire life the woods and meadows, hedges and swamps, streams and lakes of his beloved Concord were sources from the sympathetic study of which he obtained a fund of rare knowledge and to which he constantly turned for consolation and inspiration. He was graduated from Harvard in 1837 and for some years thereafter was engaged in teaching. Later he became a professional surveyor, which work was more congenial than the schoolroom in that it gave him a longed-for opportunity to tramp over the fields and scramble over the hills and to devote

[2] Howard, L. O. "Progress in Economic Entomology in the United States." Yearbook U. S. Dept. Agriculture, 1899, pp. 135–156. 1900.

long hours to intensive study of plants, birds, insects and other natural phenomena. His observations were recorded daily in his journal, and this writing was done with a sympathy, an insight and a fidelity to detail seldom equalled elsewhere and the contents often were couched in language of rare beauty. This journal, in its original form consisting of thirty large manuscript volumes, published in 1906, comprises over 7,800 printed octavo pages. It was begun in 1837 in his twentieth year, continued uninterruptedly down to his death and covered a period of twenty-five years. In some respects it is probably one of the most extraordinary productions in American literature. During the later years of his life, Thoreau spent the greater part of his time as lecturer and author. His "Week on the Concord and Merrimack Rivers," issued in 1849, is a narrative of a boat trip taken with his brother in August, 1839, and is full of admirable description and minute observations of nature, with occasional digressions into philosophy, history and classical literature. His second book, "Walden," issued in 1854, is an account of the author's residence for two years, beginning in 1845, as a naturalist and writer, in a tiny hut on the shores of a small pond near his native village. This is his most popular work and is "recognized as one of the most original and sincere publications in American letters and one of the most genuine of woodland books." Only these two volumes were issued during his lifetime, though others were posthumously edited from the journal accounts of some of his short expeditions over New England, notably "Excursions," 1863; "The Maine Woods," 1864; "Cape Cod," 1865; "Spring," 1881; "Summer," 1884; "Winter," 1888, and "Autumn," 1892. The increasing interest in Thoreau and the growing appreciation of the permanent value of his work on the part of the public were evidenced by the publication of the Riverside edition of his works in eleven volumes in 1896, and the new and complete "Walden" edition in twenty volumes in 1906.[3] This edition includes the publication, for the first time, of the journal in its entirety as written and this comprises fourteen of the volumes. Some of his best essays are perhaps not to be excelled in American literature, and, as one writer has put it, "it may be doubted whether the work of any of his contemporaries is wearing so well."

Said Emerson concerning him:

> It was a pleasure and a privilege to walk with him. He knew the country like a fox or a bird, and passed through it as freely by paths of his own. He knew every track in the snow or on the ground, and what creature had taken this path before him. Under his arm he carried an old music book to press plants; in his pocket his diary and pencil, a spy-glass for birds, microscope, jack-knife and twine. He drew out of his breastpocket his diary and read the names of all the plants that should bloom on this day, whereof he kept account as a banker when his notes fall due. The cypripedium not due till to-morrow. He thought if waked up from a trance in this swamp, he could tell by the plants what time of the year it was within two days.

There were people who criticised Thoreau as being an eccentric loafer or an impractical dreamer. It is not known who all these were. Apparently their sole claim to immortality lies in the fact that they criticised Thoreau. "The cur barks at the moon, but the moon still shines on." On the other hand, scarcely ever was a man more fortunate in the character of his friendships or more profoundly influenced by them. Perhaps, too, there scarcely ever was a man more fully appreciative of them. In addition to Harris, it is known that Thoreau was on terms of more or less intimate friendship with, and that a number of his field and woodland expeditions were taken in

[3] "The Writings of Henry David Thoreau." Walden edition, 20 volumes. Boston. Houghton. 1906.

the company of, such stimulating and inspiring associates as Ralph Waldo Emerson, Louis Agassiz, William Ellery Channing, A. Bronson Alcott, Margaret Fuller, Edward Hoar, Louisa May Alcott, Nathaniel Hawthorne, Frank B. Sanborn,[4] Horace Greeley, Walt Whitman, Daniel Ricketson, H. G. O. Blake and Thomas Cholmondeley. One might envy those old-time observers both their associations and the comparatively virgin field in which they worked did not one realize how truly to-day the "great ocean of truth still lies all undiscovered before us."

Curiously enough, in 1861, Thoreau, who had spent the greater part of his life in the open, contracted tuberculosis—a fact in defiance of our modern notions regarding control of that disease. After a heart-breaking trip to Minnesota in vain search for a more favorable climate, he returned to Concord and died there on May 6, 1862, in his forty-fifth year, having outlived his friend by only seven years. At the time of his funeral Emerson said of him:

> The country knows not yet, or in the least part, how great a son it has lost. His soul was made for the noblest society; he had in his short life exhausted the capabilities of the world; wherever there is knowledge, wherever there is virtue, wherever there is beauty, he will find a home.

The temptation to a compiler is very great to quote copiously from the references in Thoreau's journal to his friendship with Dr. Harris. Limitations of space and a wholesome fear of the editorial blue pencil, however, forbid more than the inclusion of a few of the more typical records of the visits and conversations of these two friends. It is easy from these scattered entries to visualize the free and easy comradeship which existed between them and to apprehend something of the zest and delight with which at every meeting they discussed and pored over their entomological treasures. Especially evident always are the care manifested by that born teacher, Dr. Harris, in imparting knowledge to his younger associate fully and clearly from his vast fund of information and the sympathetic interest manifested by him in the identification of material brought in to him from time to time in earlier years by his protégé. The following passage, under date of July 26, 1852, from the Journal (v. 4, pp. 259–260), is typical of this:

> Went to Cambridge and Boston to-day. Dr. Harris says that my great moth is *Attacus luna*; may be regarded as one of several emperor moths. They are rarely seen, being very liable to be snapped up by birds. Once, as he was crossing the College yard, he saw the wings of one coming down, which reached the ground just at his feet. What a tragedy! The wings came down as the only evidence that such a creature had soared—wings large and splendid, which were designed to bear a precious burden through the upper air. So most poems, even epics, are like the wings come down to earth, while the poet whose adventurous flight they evidence has been snapped up by the ravenous vulture of this world. If this moth ventures abroad by day, some bird will pick out the precious cargo and let the sails and rigging drift, as when the sailor meets with a floating spar and sail and reports a wreck seen in a certain latitude and longitude. For what were such tender and defenseless organizations made? The one I had, being put in a large box, beat itself—its wings, etc.—all to pieces in the night, in its efforts to get out, depositing its eggs, nevertheless, on the sides of its prison. Perchance the entomologist never saw an entire specimen, but as he walked one day, the wings of a larger species than he had ever seen came fluttering down. The wreck of an argosy in the air. He also tells me the glow worms are first seen, he thinks, in the latter part of August; also that there is a large and brilliant glow worm found here, more than an inch long, as he measured it on his finger, but rare.

It appears that other and random topics of conversation on such visits also made sufficient impression upon the mind of the writer to be recorded, for, on January 1, 1853,[5] he says:

[4] Sanborn, F. B., "Life of Henry David Thoreau." Boston. Houghton. 1917.

[5] "Journal," v. 4, pp. 439–440.

Being at Cambridge day before yesterday, Sidley told me that Agassiz told him that Harris was the greatest entomologist in the world, and gave him permission to repeat his remark. As I stood at the top of a ladder, he came along with his hand full of papers and inquired, "Do you value autographs?" "No, I do not," I answered slowly and gravely. "Oh, I didn't know but you did. I had some of Governor Dunlap," said he, retreating.

And again, on February 9, 1853:[6]

At Cambridge to-day. Dr. Harris thinks the Indians had no real hemp but their apocynum, and, he thinks, a kind of nettle, and an asclepias, etc. He doubts if the dog was indigenous among them. Finds nothing to convince him in the history of New England. Agassiz asked him what authority there was for it. Thinks that the potato which is said to have been carried from Virginia by Raleigh was the ground nut (which is described, I perceived, in Debry (Heriot?) among the fruits of Virginia), the potato not being indigenous in North America, and the ground-nut having been called wild potato in New England, the north part of Virginia, and not being found in England. Yet he allows that Raleigh cultivated the potato in Ireland.

There are also occasional entries, which at first may come as a bit of surprise to a professional entomologist, that the young man should find it necessary to go to his mentor for identification of material now considered exceedingly common. It should be realized, however, that notes like the following were made seventy-two years ago and concerned species that possibly may have been comparatively rare at that time:

To Haverhill via Cambridge and Boston. Dr. Harris says that that early black-winged buff-edged butterfly is the *Vanessa antiopa*, and is introduced from Europe, and is sometimes found in this state alive in winter. The orange-brown one with scalloped wings, and smaller somewhat, is *Vanessa progne*. The early pestle-shaped bug or beetle is a *Cicindela*, of which there are three species, one of them recognized from a semicolon-like mark on it.[7]

To Boston. Channing says he saw skater insects to-day. Harris tells me that those gray insects within the little log forts under the bark of the dead white pine, which I found about a week ago, are *Rhagium lineatum*.[8]

Went to Cambridge to court. Dr. Harris says that my cocoons found in Lincoln in December are of the *Attacus cecropia*, the largest of our emperor moths. He made this drawing of the four kinds of emperor moths which he says we have. The *cecropia* is the largest. The cocoon must be right end uppermost when they are ready to come out. The *A. promethea* is the only moth whose cocoon has a fastening wound around the petiole of the leaf, and round the shoot, the leaf partly folded around it. That spider whose hole I found, and which I carried him, he is pretty sure is the *Lycosa fatifera*. In a large and splendid work on the insects of Georgia, by Edwards and Smith (?) near end of last century, up-stairs, I found plates of the above moths, called not *Attacus*, but *Phalaena*, and other species of *Phalaena*. He thinks that small beetle, slightly metallic, which I saw with grubs, etc., on the yellow lily roots last fall was a *Donax* or one of the *Donasia* (?).[9]

One can well picture the delight and the enthusiasm with which congenial spirits would discuss a finding of such momentous importance as the following:

Dr. Harris described to me his finding a new species of *Cicindela* at the White Mountains this fall, the same of which he had found a specimen there some time ago, supposed to be very rare, found at Peter's River and Lake Superior; but he proves it to be common near the White Mountains.[10]

Or the intensity of interest with which they would debate some such point as the following:

Saw at Farmer's, his snow-grubs—the same I had seen (Vide back). Harris, in this week's *New England Farmer*, thinks, on comparing them with English plates, that they are the larvae of one of the species of cranefly (*Tipula*). I saw some still in F's pasture. Did they come out from the roots of grass prematurely in the winter, and so become food for birds?[11]

[6] "Journal," v. 4, p. 491.
[7] April 11, 1853, "Journal," v. 5, p. 109.
[8] March 13, 1854, "Journal," v. 6, p. 166.
[9] January 19, 1854, "Journal," v. 6, p. 73.
[10] Nov. 28, 1853, "Journal," v. 5, pp. 521–522.
[11] April 1, 1854, "Journal," v. 6, p. 181.

Or, again, their penchant for comparison of data like the entry for June 13, 1854:[12]

Caught a locust—properly harvest fly (*Cicada*)—drumming on a birch which Bacon and Hill (of Waltham) thinks like the *septendecim*, except that ours has not red eyes but black ones. Harris's other kind, the dog-day *Cicada* (*canicularis*), or harvest-fly. He says it begins to be heard invariably at the beginning of dog days; he (Harris) heard it for many years in succession with few exceptions on the 25th of July.

And, January 16, 1855:[13]

To Cambridge and Boston. Carried to Harris the worms—brown, light striped, and fuzzy black caterpillars (he calls the first also caterpillars); also two black beetles; all which I have found within a week or two on ice and snow; thickest in a straw. Showed me, in a German work, plates of the larvae of dragon flies, and ephemarae, such as I see—or their cases—on rushes, etc., over water. Says the ant-lion is found at Burlington, Vermont, and *may* be at Concord.

The creaking or shrilling of crickets long appeared to possess a fascination for Thoreau, for he has referred to it again and again in his writings in entries which were scattered over a long period of years. Occasionally he speaks of it in words of rare beauty and high poetic import. A large volume might well be filled with quotations from his Journal on this topic alone. Perhaps the following, chosen at random, will indicate their general tenor:

As I climbed the hill again toward my old bean-field, I listened to the ancient, familiar, immortal, dear cricket sound under all others, hearing at first some distinct chirps; but when these ceased I was aware of the general earth-song, which my hearing had not heard, amid which these were only taller flowers in a bed, and I wondered if behind or beneath this there was not some other chant yet more universal. Why do we not hear when this begins in the spring? and when it ceases in the fall? or is it too gradual?[14]

And:

Be ever so little distracted, your thoughts so little confused, your engagements so few, your attention so free, your existence so mundane, that in all places and in all hours you can hear the sound of crickets in those seasons when they can be heard. It is a mark of serenity and health of mind when a person hears this sound much—in streets or cities as well as in fields. Some ears never hear this sound; are called deaf. Is it not because they have so long attended to other sounds?

Why was there never a poem on the cricket? Its creak seems to me to be one of the most prominent and obvious facts in the world, and the least heeded. In the report of a man's contemplations I look to see somewhat answering to this sound.

It is evident that Thoreau and Harris included the topic in some of their long all-embracing conversations. Under date of October 19, 1857,[15] is this entry:

Harris says the crickets produce their shrilling by shuffling their wing-covers together *lengthwise*. I should have said it was sidewise, or transversely to the insect's length, as I looked down on it. You may see these crickets now everywhere in the ruts, as in the cross-road from the turn pike to the Great Road, creeping along, or oftenest three or four together, absorbed in feeding on, *i.e.*, sucking the juices of, a crushed companion. There are two broad ruts made by oxcarts loaded with muck, and a cricket has been crushed or wounded every four or five feet in each. It is one long slaughter-house. But as often as a cart goes by, the survivors each time return quickly to their seemingly luscious feast. At least two kinds are there.

Occasionally he dwells in characteristic strain upon sounds made by other insects. Can we imagine a twentieth century orthopterist at the close of a busy day in the field methodically making an entry like this in his notes:[16]

The crackling flight of grasshoppers is a luxury; and pleasant is it when summer has once more followed in the steps of winter to hear scald cricket piping a Nibelungenlied in

[12] "Journal," v. 6, p. 348.
[13] "Journal," v. 7, p. 116.
[14] June 13, 1851, "Journal," v. 2, p. 254.
[15] "Journal," v. 10, p. 108.
[16] "Journal," v. 1, p. 57.

the grass. It is the most infinite of singers. Wiselier had the Greeks chosen a golden cricket, and let the grasshoppers eat grass. One opens both his ears to the invisible, incessant quire, and doubts if it be not earth herself chanting for all time.

There is no doubt but that matters other than those entomological engrossed a portion of their attention when together. Witness the entry under date of December 7, 1854:[17]

Harris tells me that since he exchanged a duplicate Jesuit Relation for one he had not with the Montreal men, *all* theirs have been burnt. He has two early ones which I have not seen.

One thinks, parenthetically, that the two friends surely would have gloated over it could they have been permitted to live long enough to see and study the monumental translation of that voluminous mine of historical and biological information, "The Jesuit Relations," which work has been so ably performed in our own generation by that eminent historian, Reuben G. Thwaites.

It will be remembered in this connection that Dr. Harris, by virtue of his position as librarian, was often consulted as an expert in genealogical matters and that his interest in the subject was very real is evidenced by the fact that at the time of his death he had in course of preparation a very elaborate genealogical history of the Mason family. If he was forbidden by a perverse fate to be entirely an entomologist, he could yet derive enjoyment from his position as a librarian. Indeed the versatility of his interests is indicated more than once in the records left by his friend. Instance the note regarding his botanical observations.

After discussing in some detail the plants in Andromeda Ponds, Thoreau adds:[18]

Dr. Harris spoke of this andromeda as a *rare* plant in Cambridge. There was one pondhole where he had found it, but he believed they had destroyed it now getting out the mud. What can be expected of a town where this is a rare plant? Here is Nature's parlor; here you can talk with her in the *lingua vernacula*, if you can speak it—if you have anything to say—in her little back sitting-room, her withdrawing room, her *keeping* room.

In connection with the publication of the famous treatise by Dr. Harris on "Insects Injurious to Vegetation" we find a characteristic comment. Surely Thoreau must have had his tongue in his cheek when he penned these words:[19]

We accuse savages of worshipping only the bad spirit, or devil, though they may distinguish both a good and bad; but they regard only that one which they fear and worship the devil only. We too are savages in this, doing precisely the same thing. This occurred to me yesterday as I sat in the woods admiring the beauty of the blue butterfly. We are not chiefly interested in birds and insects, for example, as they are ornamental to the earth and cheering to man, but we spare the lives of the former only on condition that they eat more grubs than they do cherries, and the only account of the insects which the State encourages is of the "Insects Injurious to Vegetation." We too admit both a good and bad spirit, but we worship chiefly the bad spirit, whom we fear. We do not think first of the good but of the harm things will do us.

The catechism says that the chief end of man is to glorify God and enjoy him forever, which of course is applicable mainly to God as seen in His works. Yet the only account of its beautiful insects—butterflies, etc.—which God has made and set before us which the State ever thinks of spending any money on is the account of those which are injurious to vegetation! This is the way we glorify God and enjoy Him forever. Come out of the herd and behold a thousand painted butterflies and other beautiful insects which people the air, then go into the libraries and see what kind of prayer and glorification of God is there recorded. Massachusetts has published her report on "Insects Injurious to Vegetation," and our neighbor the "Noxious Insects of New York." We have attended to the evil and said nothing about the good. This is looking a gift horse

[17] "Journal," v. 7, p. 80.

[18] January 24, 1855, "Journal," v. 7, pp. 138–139.

[19] May 1, 1859, "Journal," v. 12, pp. 170–171.

in the mouth with a vengeance. Children are attracted by the beauty of butterflies, but their parents and legislators deem it an idle pursuit. The parents remind me of the devil, but the children of God. Though God may have pronounced His work good, we ask, "Is it poisonous?"

There are occasional present-day unlovely exhibitions of professional jealousy, those straws on the stream indicating the character and trend of the current beneath, that tend sometimes to make one wonder if it would not produce a salutary and wholesome effect upon some members of the twentieth century scientific fraternity occasionally to review for purposes of emulation some of these old-time friendships with their freedom from such strains of coarseness. Thoreau, always keenly sensitive to the touch of every form of beauty, has written much of friendship and its loveliness, descriptive of such as existed between Harris and himself. Perhaps some disgruntled individuals might have to stand on tiptoe even to read words like the following about a contemporary,[20] written by the man who might have been "a splendid entomologist if he had not been spoiled by Emerson":

As surely as the sunset of my latest November shall translate me to the ethereal world, and remind me of the ruddy morning of youth; as surely as the last strain of music which falls on my decaying ear shall make age to be forgotten . . . so surely my Friend shall forever be my Friend and reflect a ray of God to me, and time shall foster and adorn and consecrate our Friendship. . . . As I love nature, as I love singing birds, and gleaming stubble, and flowing rivers, and morning and evening, and summer and winter, I love thee, my Friend.

[20] "Week," p. 303.

GEOLOGIC ROMANCE OF THE FINGER LAKES

By Professor HERMAN L. FAIRCHILD
UNIVERSITY OF ROCHESTER

SUPERLATIVES have been exhausted in praising the Parallel Lakes of New York. They deserve the praise. But the beauty of the lakes and the charm of their setting are not more deserving than is the dramatic story of their making.

In the lakes themselves there is no mystery. The water-bodies merely fill the land depressions to overflowing. The romantic interest lies in the origin and history of the basins which hold the lakes.

A misleading theory in former years, which yet appears in print, claimed that the basins were scooped out by a plowing action of the ice sheet of the Glacial Period. This explanation, which was even applied to the great Ontario basin, was a popular and easy way of avoiding a complex problem in New York physiography. The fact that the bottom of Lake Cayuga is fifty-four feet below ocean level, that of Seneca one hundred and seventy-four feet, and that of Ontario nearly five hundred feet, was the singular and puzzling feature. But the Quebec glacier, which overspread New York and New England and which admittedly had some abrading effect, was not guilty of the valley deepening; although it had some part in producing the basins.

The purpose of this writing is to describe the formation of the Finger Lakes basins—a romance in geology. The physical conditions and the length of time are so far beyond human experience that to appreciate the facts of the story requires of the reader some mental exercise, with constructive imagination. Many people do not like facts, if new, but prefer a world of unreality.

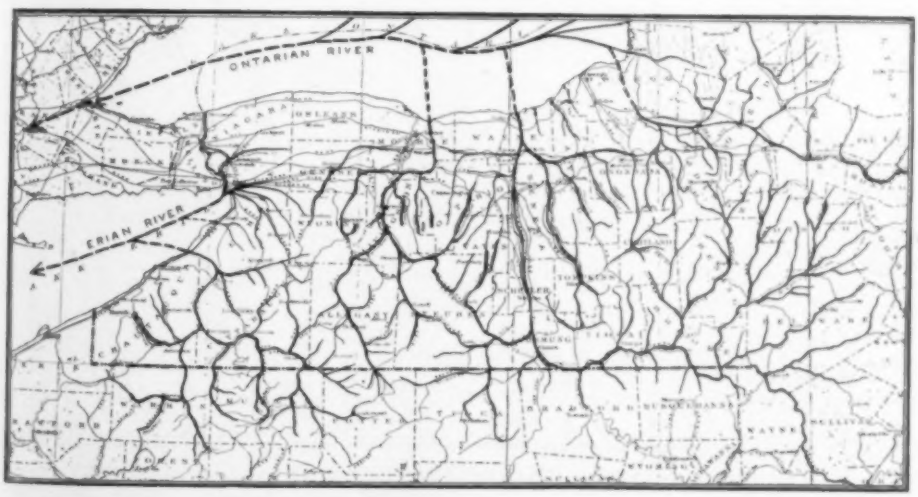


FIG. 1. LATE TERTIARY, OR PREGLACIAL, DRAINAGE OF CENTRAL AND WESTERN NEW YORK

GLACIAL DRIFT HAS SO OBSCURED THE ANCIENT RIVER COURSES, ESPECIALLY OVER A WIDE BELT NEAR LAKE ONTARIO, THAT THE MAPPING IS PARTIALLY HYPOTHETIC

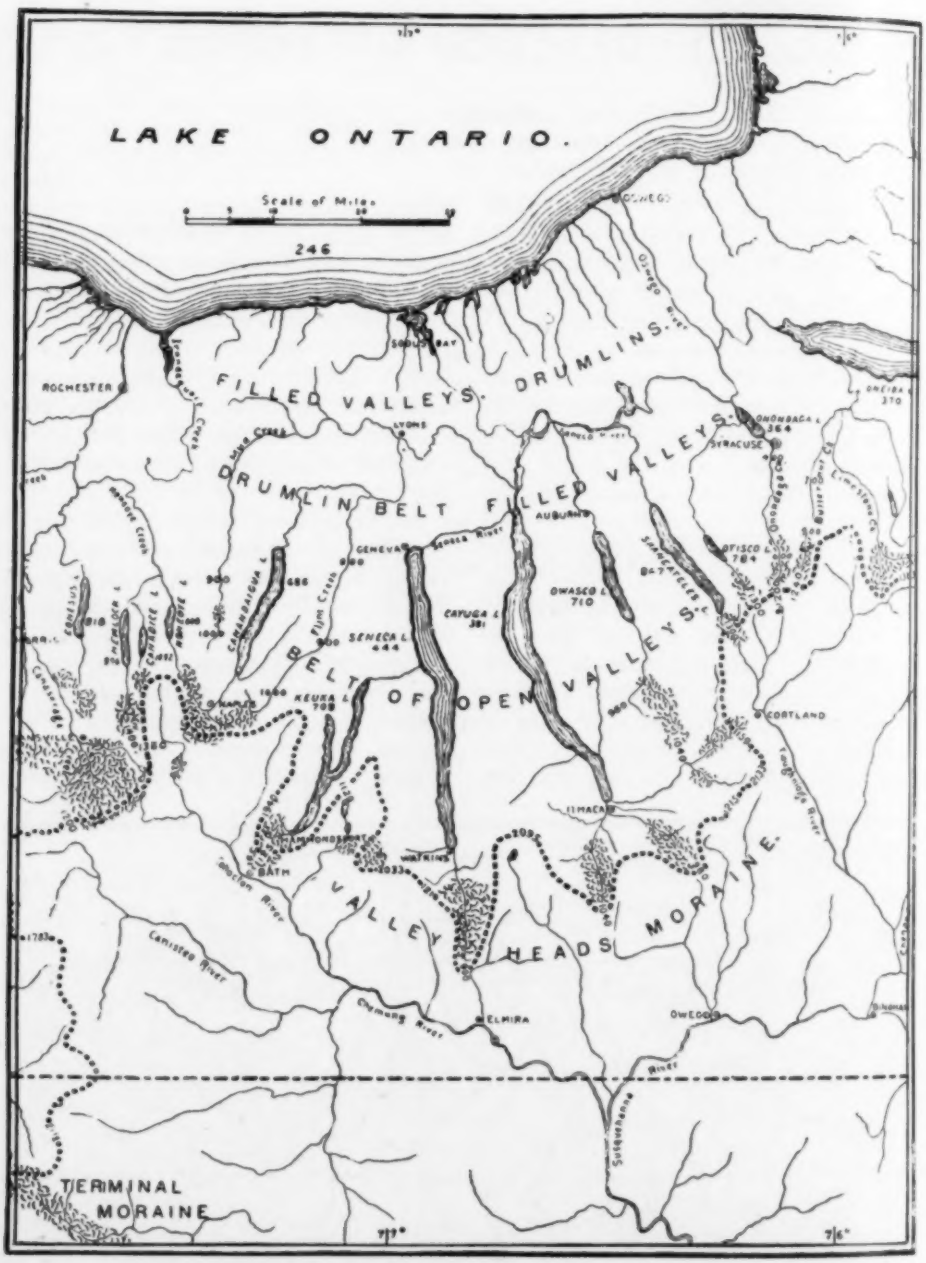


FIG. 2. FINGER LAKES AND PHYSIOGRAPHIC BELTS IN CENTRAL NEW YORK

If the reader happens to be of the latter class he would better break away right here. Yet the story, like many truths of nature, surpasses any fiction of man's invention.

We are so familiar with many lakes,

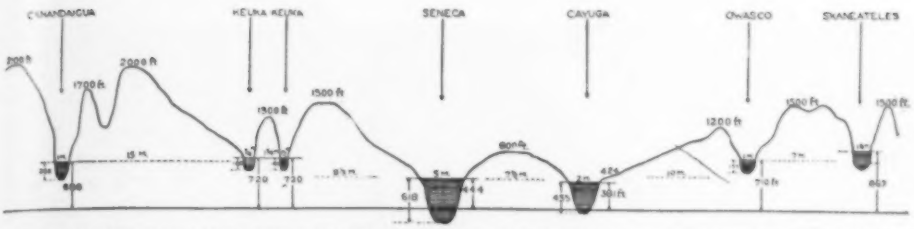


FIG. 3. PROFILE OF LAKE REGION SHOWING DEPTH AND GREATEST WIDTH OF LAKES. BASE LINE IS SEA LEVEL

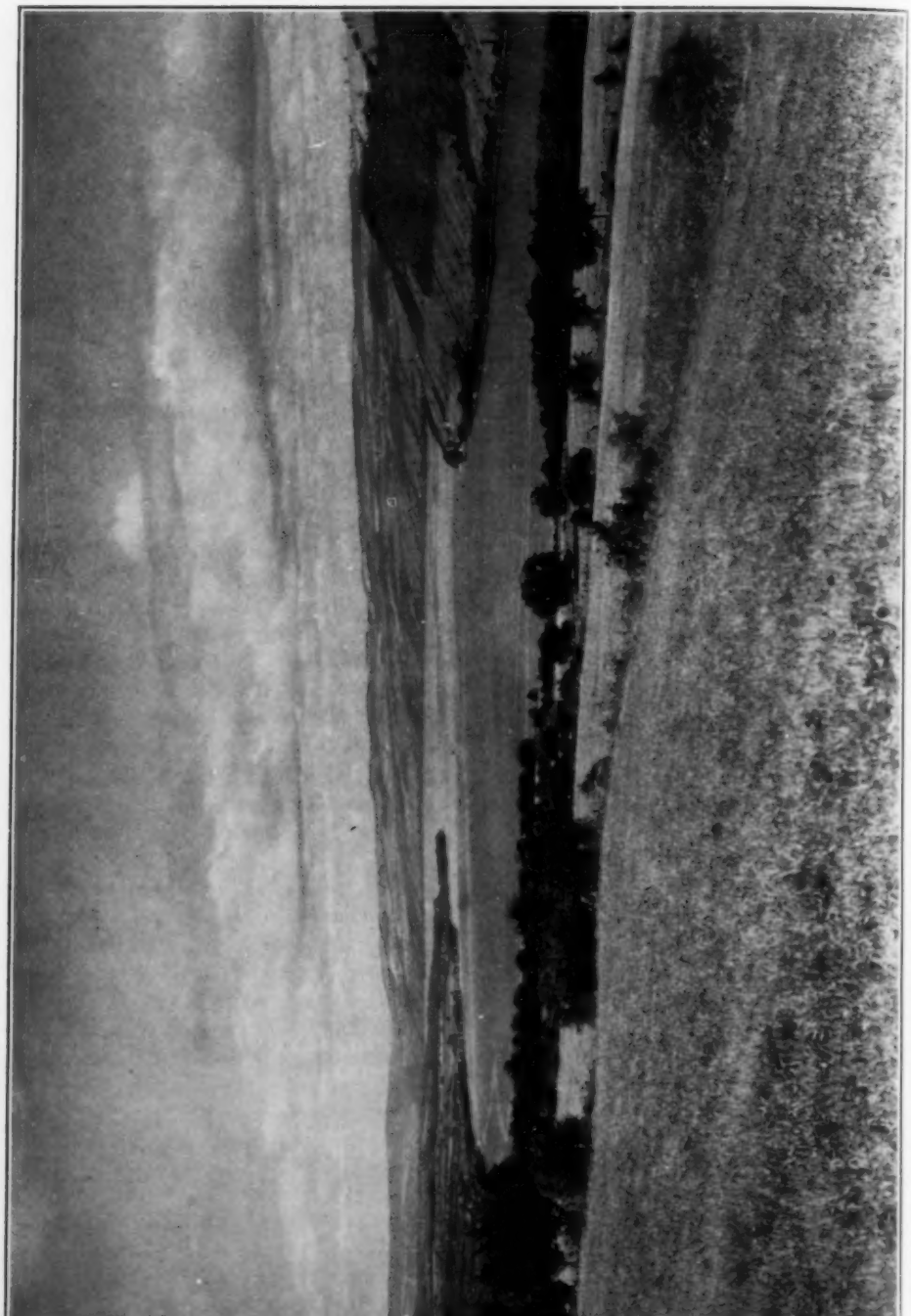
large and small, that they seem to be normal and permanent features. On the contrary, they are unusual, exceptional and transitory. Excepting the peculiar ones in Florida and on the Mississippi delta there are few lakes to-day in America, outside of glaciated territory. The ox-bows in the flood plains of rivers are not counted.

Most lakes may be defined as expansions of streams. But the basins or reservoirs are not made by the streams in normal flow. Some external interference or damming effect is necessary. Streams can not permanently dam themselves. Ice-jams, log-jams and landslides make temporary reservoirs. The singular and beautiful lakelets near Syracuse, one in a state park, occupy cataract plunge-basins, and are of very exceptional and interesting character. With their bounding cliffs they are fossil Niagaras. To-day Niagara Falls is drilling a similar bowl. The Syracuse basins were carved by rivers which in function were true predecessors of Niagara. They were held up in forced flow by the front of the waning glacier. Perhaps they are the best example of streams making basins. But these lakelets did not exist while the rivers were flowing.

FIG. 4. DETRITAL FILLING AT THE HEAD OF SENECA LAKE

In regions of land movement, as mountain districts, basins are sometimes produced by the bending and the breaking of the earth's crust. The Jordan Valley and Dead Sea is example of the latter. The basin of Lake Superior is thought to be due in part to crustal warping. But the basins of the Finger Lakes are in practically horizontal strata, lifted out of the sea and without serious deformation.

As reckoned in geologic time, lakes are short-lived. They disappear either by the downcutting of their outlets or by the filling of their basins. Sand and silt are swept in by streams and by winds in arid regions, and vegetable growth assists the filling process. Shal-



LAKE KEUKA

VIEW OF WEST FORK: LOOKING SOUTH—CHARACTERISTIC TOPOGRAPHY OF THE FINGER LAKES VALLEYS

Photo by Barnett

low lakes which recently existed in some of the New York valleys have already become plains or swamps. The extensive plains at the heads of the Finger Lakes, Seneca and Cayuga, for example, show the rapid filling by the detritus swept in by the inlet streams.

The scores of thousands of lakes and lakelets in our northern states and Canada came into very recent existence with the melting away of the Canadian ice sheets. Previous to the glacial invasions there were few, if any, lakes in eastern America. This implies that the Finger Lakes are not old. Indeed, they are very young, speaking in geologic lingo. Their life is reckoned only in tens, or at most, in scores of thousands of years. But the valleys in which they lie have been in the making for uncounted millions of years. The Finger Lakes are about the latest geologic features in the state. The cataracts and canyons are younger. Lake Ontario is the youngest great physiographic feature in America.

The origin of the Parallel Valleys must first be learned, and then how they came to be dammed. This series of parallel valleys is probably the most notable in the world. That may sound like American bravado, but the challenge stands. Starting with the upper Tonawanda (Attica) valley on the west, and passing eastward, the other pronounced valleys are: Oatka (Warsaw); Genesee; Conesus; *Hemlock; Canadice; Honeoye;* Mud Creek (Bristol); *Canandaigua;* Flint Creek (Gorham-Orleans); *Keuka; Seneca; Cayuga; Owasco; Skaneateles; Otisco; Onondaga;* Butternut (Jamesville); Limestone (Fayetteville); Chittenango; Cowaselon; *Oneida.* The valleys which now hold lakes are marked by italics. (See figure 1.)

All these valleys drain northward into Lake Ontario. The series might fairly include a number west of the Tonawanda, that swing around into Lake Erie, and others on the east which lead into the Mohawk River. Some of the valleys, as the Oatka, Genesee and Flint, once held lakes that are now represented by plains.

The making of these north-leading valleys is a part of the story which makes demand on the scientific imagination. The history covers the many millions of years since central and western New York were permanently lifted out of the sea. The clear record of the long marine submergence is seen in the rock strata, several thousand feet in thickness, filled with remains of the varied life of the ancient seas. Remnants of the nearly horizontal strata constitute the broad, arching ridges between the valleys, with elevations up to over two thousand feet above sea-level. The valleys are the positive effect, having been carved by atmospheric and stream erosion out of the uplifted land.

When the area of the western part of New York had been permanently raised out of the sea it was a vast plain, declining southward. The Ontario and Mohawk valleys did not exist. All the stream drainage of the area was southward, from Canada across New York into Pennsylvania. A wide belt of comparatively weak rocks lay east and west where the Ontario and Mohawk valleys are now. In that belt the east and west tributaries of the primitive south-flowing rivers had an advantage, on account of the weaker resistance of the underlying rocks. They cut down faster and captured, or "beheaded," the rivers from Canada and developed the east-and-west depression that initiated the Ontario and Mohawk valleys.

Eventually a great trunk river, which we call Ontarian, occupied the depression that is now the Ontario Valley, probably flowing westward to the Mississippi. Of course this great valley had two walls or drainage slopes. On the south wall, sloping northward, the

VIEW OF WEST FORK; LOOKING NORTH—CHARACTERISTIC TOPOGRAPHY OF THE FINGER LAKES VALLEYS

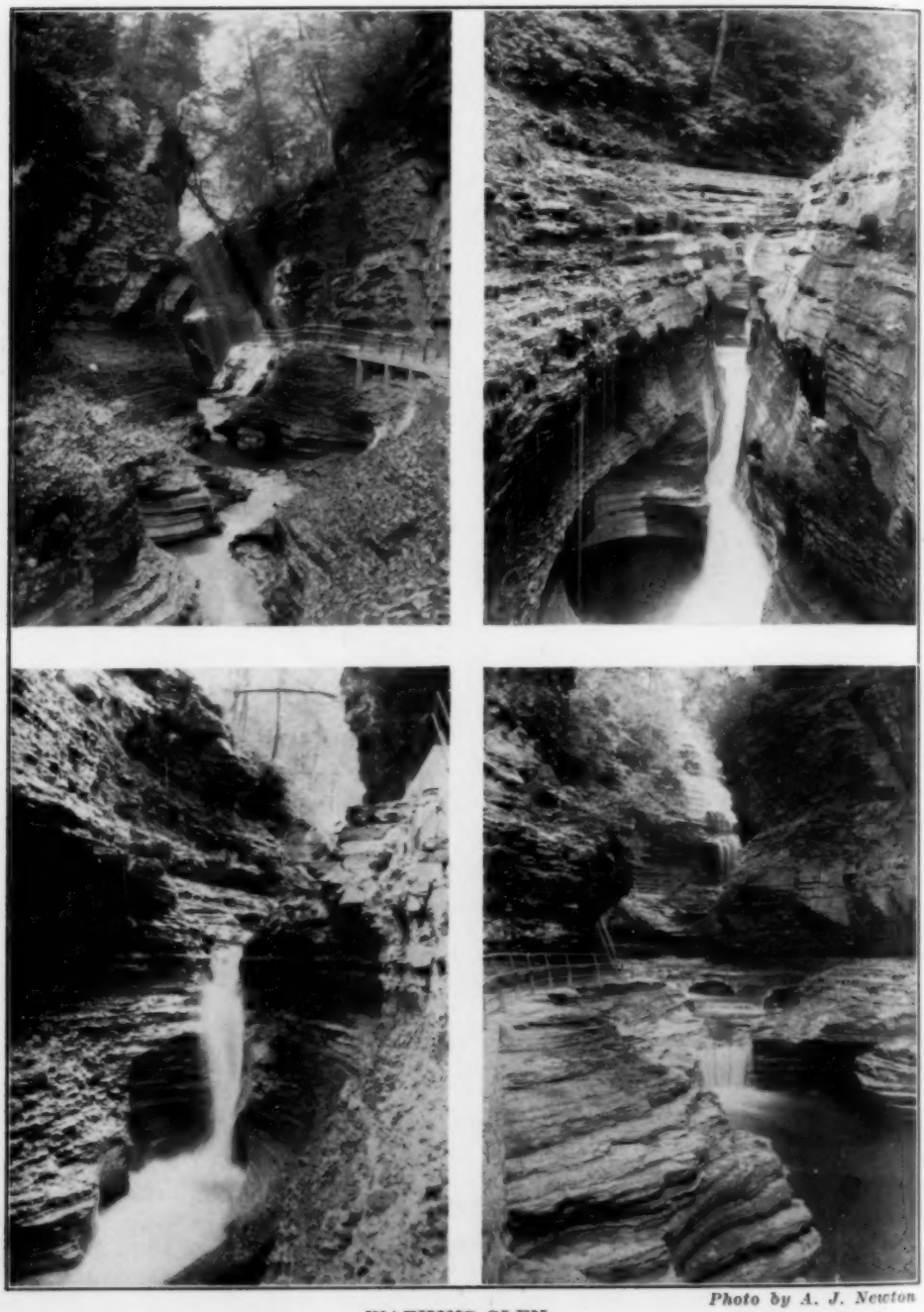


Photo by A. J. Newton

WATKINS GLEN

Photo by C. A. Payne

CAVERN CASCADE: WATKINS GLEN

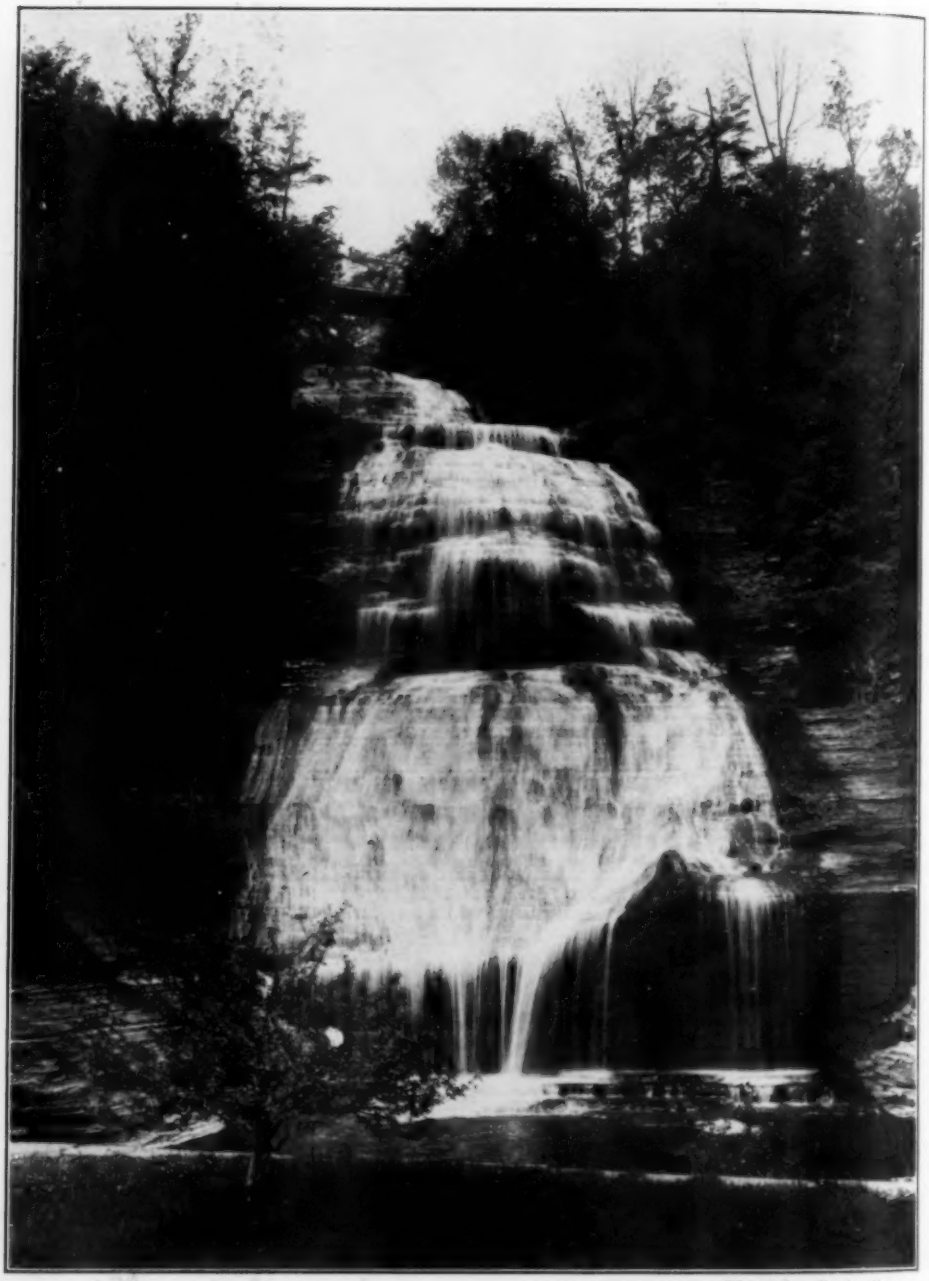


Photo by C. A. Payne

CHEQUAGA FALLS

In glen of Montour Falls, head of Seneca Valley

streams flowed *northward* into the Ontarian River. During the long geologic time, probably part of the Mesozoic Era, or Age of Reptiles, and certainly during the succeeding long Tertiary Period, or Age of Mammals, the Ontario Valley was deepening and widening. Its tributaries from the south were doing the same, and by headward erosion were eating back, southward, into the highland of the southern belt. Eventually these north-flowing rivers deeply intrenched the highland, even into Pennsylvania. Thus all western New York and a belt of northern Pennsylvania was drained north into either the Ontarian or the Erian rivers (See the map, figure 1).

It must be recognized that this northward New York drainage was the reverse in direction of the original, or primitive, flow on the old coastal plain. Of course the Canadian streams retained their southward flow, as seen to-day, until they reached the Ontarian River. The upper Susquehanna and its upper tributaries are probably persistent examples of the primitive southward flow, but they have been beheaded by the Mohawk, flowing eastward.

The parallel valleys of New York were carved in preglacial time by north-flowing rivers; with the possible exception of Canandaigua and Keuka valleys, which appear to have retained, through some distance, the primitive southward flow. But even their streams became tributary to the northward flow (figure 1). If we ever have a geographic survey of the buried rock topography it will doubtless show that the bottoms of the Irondequoit, Seneca and Cayuga valleys are graded to the bottom of Lake Ontario. This will fully account for the depths of the unfilled portions of these valleys.

One surprising element in the reversed drainage, shown in the map, was the capture of the old Susquehanna River. First it was diverted to westward flow, as retained to-day, through Binghamton, Owego and Waverly. But it is believed that it was turned northward at Elmira and did the chief work of deepening the Seneca Valley. We might call this great river the Senecahanna, or the Susqueseneca. Most of the northward drainage in New York appears to have been concentrated in the Genesee and the Susqueseneca.

We now have found the origin of the parallel valleys. Three questions now occur. Why the valleys are cut below sea-level; how they were dammed, to hold lakes; and the cause of the digital arrangement, like fingers on the palm of the hand.

It is difficult for people in quiet portions of the continent to realize that the land is not fixed and eternal. People in earthquake-ridden areas know better. Even continental areas move slowly up and down. During the long eons while the valleys were making, the land of eastern America was probably seesawing, up and down, as it had been doing in earlier time. Just previous to the Glacial Period it probably stood much higher than it is to-day, possibly two or three thousand feet. Certainly the bottom of the Ontario Valley was high enough to allow efficient flow to the sea of the Ontarian River. During the long earlier history of the north-flowing rivers, with lower and more steady position of the land, the valleys were greatly widened. Later, by the Tertiary uplift, the rivers were enlivened or rejuvenated, and they sawed down more rapidly, producing the narrower, and steeper-walled, bottom sections of the valleys.

Rivers are the valley-makers. Mountain or Alpine glaciers modify the valleys which they occupy. They are chiefly agents of transportation. Their minor work of erosion tends to widen rather than deepen their channels. They change stream, or V-shaped valleys, into U-shaped. But the ice work in New York was not that of stream glaciers but that of a widespread or continental ice-sheet. It had little power of deepening valleys, but was effective rather in filling and

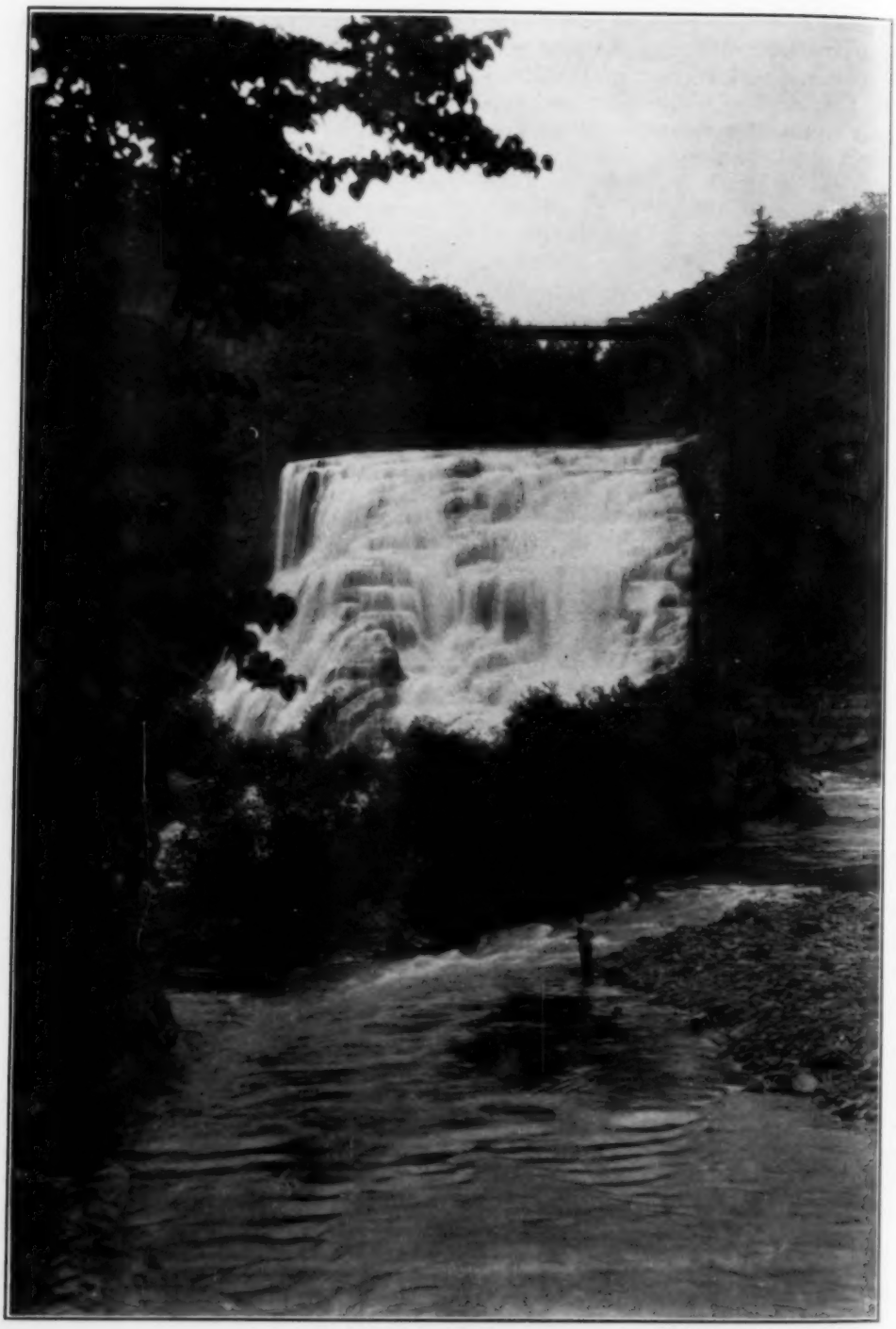


Photo by Ithaca Eng. Co.

ITHACA FALLS

BELOW THE CAMPUS OF CORNELL UNIVERSITY

damming the valleys. Lobations of the ice margin pushed into the old valleys, during both the oncoming and the recession of the glacier. But the lobes, pushing up the valleys, with imprisoned lakes facing them, were heavily loaded with rock-rubbish (glacial drift), and had little power of erosion. Moreover, the bottom ice in the deep valleys is believed to have been comparatively stagnant, serving as the bridge for the flow of the plastic upper ice. When the ice-sheet was thick it moved southwestward, or diagonally across the central valleys. And, as noted above, the later lobations were too heavily loaded with bottom drift to do effective cutting. They piled their drift burden mostly in the hummocky deposits that now make the divides or water-parting south of the lakes (see figure 2).

In general the ice-sheet had only a smoothing or sandpapering effect on the land surfaces. It rubbed down the projections and filled the depressions, thus producing the remarkably uniform curving surfaces which give the slopes of the Finger Lakes valleys their graceful outlines.

During the later stand of the Quebec ice-sheet it completely filled the northern ends of the valleys with its drift deposit, forming the wide plains north of the lakes. This drift filling makes the dams that hold the lakes.

In addition to this northern blocking of the valleys another agency has helped to make the basins. This is the tilting uplift of the land. The weight of the Quebec ice-cap, many thousand feet thick, depressed the land. When the ice was removed the land rose, slantingly in New York. The amount of slant, or uptilting, has raised the north ends of Cayuga and Seneca lakes about eighty feet more than the south ends. As the outlets are at the north ends it is evident that the land movement is partly responsible for the lake basins.

However, the "basin" character has been overemphasized. A true vertical profile of the basins shows that they are comparatively shallow. If the depth of Lake Seneca (618 feet) be represented on a diagram by one inch, then the length of the lake (thirty-six miles) would be twenty-six feet. On the same scale the length of Cayuga would be forty feet. And if the depth of Ontario be diagrammed as one foot, the length of the lake would be nearly one fourth of a mile. Evidently, no appeal is necessary to a fanciful deepening by "glacial erosion."

The singular direction of the central valleys, converging northward, is an effect of the stream flow being directed by the general slope of the broader land surfaces; and the latter being determined by the character of the rocks in which the valleys were carved. As stated above, the east and west Ontario-Mohawk depression was initiated on the outcropping belt of weak strata, and it became the master valley because of the great thickness of these non-resistant strata. In New York these weak strata are thickest on the meridian of Seneca and Cayuga lakes, where in the vertical series of five thousand one hundred and fifty feet of strata, between the Trenton limestone below and the Portage sandstone above, four thousand five hundred feet are weak shales, three hundred and fifty feet soluble limestone and only two hundred and fifty feet sandstone. Consequently the south wall of the great Ontario Valley in the district of the Cayuga and Seneca tributaries receded rapidly, producing the decided concavity as shown by the south shore of the present lake. Naturally the northward stream-flow was directed by the prevailing land slopes and converged toward the district of more rapid erosion.

The complex history of the Finger Lakes may be summarized as follows:

Photo by Ithaca Eng. Co.

TAUGHANNOCK FALLS

EAST SIDE OF CAYUGA VALLEY, NINE MILES NORTH OF ITHACA. THE HIGHEST CATARACT IN THE EASTERN UNITED STATES

(1) The original drainage on the uplifted sea-bottom, or coastal plain, was southward across New York from Canada. Only a few remnants of that primitive flow now exist in western New York, with the upper Susquehanna and its tributaries in the eastern district.

(2) Evolution of the great east-and-west Ontario Valley, in a wide belt of weak rocks, shales and limestone, by the Ontarian River, beheaded the Canadian rivers.

(3) Northward tributaries of the Ontarian River, on the south side of the expanding valley, ate back (southward), by head-waters erosion, into the Allegany Plateau, even to Pennsylvania. In this way was developed the remarkable series of parallel valleys; the reverse, in direction, of the original drainage (figure 1).

(4) High elevation of eastern America, in later Tertiary time, enlivened the rivers by increasing their fall to the sea, and hence their velocity. This caused rapid down-cutting of the valleys (figure 3), so producing the steeper lower walls of the central lakes, and the convexity of the slopes.

(5) The high elevation of eastern America, possibly accompanied by a slight lowering of world climate, produced vast and deep ice sheets. The latest one, the Quebec glacier, overspread New York, and subdued the state to the same condition that Greenland now suffers.

(6) In the waning of the Quebec glacier and the recession (northward) of its south front, it served as a barrier in all of the north-sloping valleys. Glacial lakes were thus held in all the valleys, and the present lakes are lineal descendants of the ice-bound lakes.

(7) During pauses in the recession of the ice front the heavy load of rock-rubbish was piled in the valleys. One great series of these frontal moraines is the heavy fillings south of the lakes. Another forms the wide plain that buries the north ends of the valleys, and produces the lake basins. (See figure 2.)

(8) Northward uptilting of the land since the weight of the ice-cap has been removed has lifted the north ends of the lakes, thus producing some increase in their depth.

(9) The filling process, by inwash of detritus and the accumulation of peat, has already obliterated some of the shallower lakes, and has made a beginning on the destruction of the remaining lakes. Witness the extensive plains at the heads of Canandaigua, Seneca, Cayuga and Owasco Lakes (figure 4).

RADIO TALKS ON SCIENCE[1]

THE PLANET MARS IN 1926

By JAMES STOKLEY

SCIENCE SERVICE, WASHINGTON, D. C.

On the twenty-second of August, two years ago, the country was very much excited about Mars. The ruddy planet shone brilliantly in the night sky, for it was only thirty-four million miles away, closer than it had been for many years or would be for many years to come. Much that was said about it was sound, scientific fact, but there was also much that was not so scientific; as, for instance, the discussion as to the possibility of the Martians, if there are any, communicating with us by radio!

But the astronomers, quietly working in the observatories, were not interested in these speculations, for they were too busy watching the planet through their telescopes, photographing it, measuring its heat and performing a host of other processes with the distant planet as their subject. Perhaps there is life on Mars or on some of the other planets, but the astronomer, as such, is not concerned in knowing whether there is or not. He can measure the light of the planet or its color, but the question of whether or not there are intelligent beings there is beyond the reach of his instruments, and so he does not bother about it.

Mars, this summer, will be a brilliant object in the morning sky. By autumn, it will be visible in the eastern sky late in the evening, until November 4, when it will be directly south at midnight and visible throughout the night, its brilliant red color leaving no doubt as to its identity. To those who watched Mars in the summer of 1924, it now comes as an old friend returning after many wanderings. On the 27th of October, 1926, when it will be closest, it will have more than completed an entire circuit of its orbit, traveling more than a billion miles, since the night of August 22nd, 1924. In the same time, the earth will have traveled more than a billion and a quarter miles in its orbit.

Last September, when Mars was on the side of the sun directly opposite the earth, the two planets were farthest apart—over 230,000,000 miles separating us from each other. But now, Mars is again coming close, and on the 27th of October it will be but 42,624,200 miles from us, farther than in 1924, but better for astronomical observation, despite the additional distance, because of the way the earth's atmosphere lets its light in to us.

On account of the atmospheric blanket which surrounds the earth, we can see a star better when it is directly overhead. When it is down near the horizon, its light passes through a much greater thickness of air, and much of the light is absorbed, a fact apparent to any one who has seen the sun just before setting.

Stars, and planets likewise, appear fainter and more unsteady when they are near the horizon. This summer Mars will be considerably higher in the sky for observers in northern countries than it was in 1924; and as most of the world's observatories are located north of the equator, the planet will be better

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of W. L. Tisdale.

situated for observation, despite its greater distance—about 25 per cent. greater than in 1924. Already the great telescopes have been trained on it, and perhaps the coming months will add as much to our knowledge of the planet as did the summer of 1924.

Of most popular interest when we speak of Mars are the so-called "canals." Discovered in 1877 by the Italian astronomer Schiaparelli, they have since been a bone of contention among astronomers. One group has supported the views of the Italian, while another has doubted their very existence, claiming that those who thought they saw them were the victims of an optical illusion.

But in 1924 better instruments than ever before were trained on the planet and the canals were reobserved by astronomers who had seen them before. Others who had previously been skeptical saw them for the first time. At the great Lick Observatory of the University of California, situated on Mt. Hamilton, near San Jose, California, Professor R. J. Trumpler watched the planet with the thirty-six inch telescope and was well rewarded for his pains. He made many drawings of the canals and what he saw was verified by Professor W. H. Pickering, at the branch station of the Harvard College Observatory at Mandeville, Jamaica, who was also making drawings of the planet at the same time. Both observers, though thousands of miles away, saw the same things!

However, a photograph is often accepted in a court of law as the best possible evidence, and when one sees a photograph of the "canals," it would seem that there is no further question of their existence. But good photographs of Mars, even with the finest instruments, are not easily made. While the photographic plate has replaced the human eye to a great degree in most branches of astronomy, observations of the planets are still best performed visually, and the best photograph of Mars that has ever been made shows but a small fraction of the detail that can be perceived by a trained observer, when looking through a powerful telescope.

One reason for this is the red color of the planet. Of all colors, red has the least effect on the ordinary photographic plate; hence a red light is used in the dark room, and when a photograph is made of Mars, the exposure must be very much longer than if the planet were blue, for example. While the exposure is being made the planet moves slightly, but this does not produce as serious an effect as the atmosphere of the earth. Continually in motion, the layers of different temperature in the air bend the rays of light from the planet first one way, then another, so that sometimes the edge of the object is sharp and distinct, and the next moment it seems to "boil."

When an experienced observer looks at such an object, the occasional glimpses that he gets when the "seeing" is good, suffice to give him an accurate idea of the general appearance. The plate, however, can not select the most favorable moments, but must take the combined appearance over a period of at least several seconds.

Despite these difficulties, photographs have been made which reveal the markings, called canals, and in fact, they had been made before 1924. In 1916, when Mars was almost as close, Mr. E. C. Slipher, at the Lowell Observatory at Flagstaff, Arizona, succeeded in recording them on the sensitive emulsion of the photographic plate. In 1924 he made still others, and Dr. Trumpler, at the Lick Observatory, also made pictures which reveal them, so it is unlikely that any astronomer will suggest in the future that the canals are optical illusions. This does not necessarily prove them to be artificial, and the general idea is that they are due to some unknown, but natural cause.

Photographs by light waves vibrating too fast or too slow to be perceptible to the eye gave valuable information to the astronomers when Mars paid its last visit. The earth's atmosphere reflects violet and the invisible ultra-violet light, but transmits the red and infra-red. Dr. W. H. Wright, of the Lick Observatory, took his camera and made photographs of the town of San Jose, which can be seen from the mountain. He used special filters and plates and made pictures by ultra-violet as well as infra-red light. Although the day was not especially hazy, in the ultra-violet pictures the town is completely obscured by what appears to be a dense fog; while those made by infra-red rays show the details of the town as though but a few feet distant.

Then Dr. Wright used the same filters and plates in the telescope to photograph Mars, and there also he found that planetary markings which were distinct with the red were entirely obliterated when the violet was used. As this was at night, when the earth's atmosphere was not illuminated, the effect was therefore almost certainly due to an atmosphere on Mars, similar to ours. But even more striking was the effect obtained when half of an infra-red picture was joined to half of one by ultra-violet light. Instead of matching, the ultra-violet image was considerably larger! This, then, was the Martian atmosphere, and by measuring the diameter of the planet in the two pictures the actual height of the layer of air on our neighbor was determined.

But even if the air is there, it might not be of quite the same composition as ours, nor need it be as dense. Indeed, observations made in 1924 at the Mt. Wilson Observatory, by Dr. Walter S. Adams and Dr. Charles E. St. John, have definitely established, they claim, that the water vapor and oxygen content in Mars' atmosphere represents only a small percentage of that found in the earth's atmosphere and is probably even rarer than that at the summit of Mt. Everest.

"The quantity of water vapor in the Martian atmosphere at the time of observation," says Dr. Adams, "was 6 per cent. of that over Mt. Wilson, or 3 per cent. of that over Pasadena. These results would indicate desert conditions over at least the greater portion of Mars. Measurements of the quantity of oxygen indicate a presence of 16 per cent. of that over an equal area of the earth's surface."

There remains one other factor that makes life possible, and that is temperature, so it is not surprising that efforts have been made to find out what the thermometer would read on Mars, if there were a thermometer there and some one to read it! Dr. W. W. Coblentz, of the Bureau of Standards, did this at the Lowell Observatory with Dr. C. O. Lampland. Using a very delicate instrument, known as the thermocouple radiometer, attached to the forty-inch reflecting telescope, he was able not only to measure the average temperature of the planet, but even to select certain areas and find out whether or not Martians in a certain section of the planet were suffering from a heat wave!

"These measurements show," according to Dr. Coblentz, "that the bright regions are cooler than the dark regions; that the sunrise side of the planet is at a lower temperature than the side under the afternoon sun; and that the polar regions are cold, emitting no planetary radiation, and having temperatures down to perhaps 90 degrees below zero Fahrenheit. The temperature of the dark part of the sunrise side of the planet is very low, probably down to 75 degrees below zero, Fahrenheit. The average of the measurements indicate that the temperature of the brightly illuminated surface of Mars is not unlike that of a cool, bright day on this earth.

with temperatures ranging from 40 to 60 degrees Fahrenheit."

Mars, then, does not seem to have conditions greatly different from those of parts of the earth. It is somewhat cooler, as it is fifty million miles farther from the sun than we are, more than half again as far from the source of energy of all the planets, but does that preclude the possibility of life there? When we consider the great variety of conditions that man is capable of surviving and the still greater variety that other forms of life can stand, it does not require any wild feat of the imagination to picture there some living organism, possibly much more primitive and quite different from any that we know. But the astronomers do not concern themselves with these imaginings. They are speculations, and the silent men in the observatories still continue to seek the facts that may come out of their researches.

HOW PLANTS BEHAVE WHEN DISEASED

By Professor B. M. DUGGAR

WASHINGTON UNIVERSITY AND MISSOURI BOTANICAL GARDEN

To you of the radio audience who may already know much about the diseases of plants I must apologize for selecting so broad a subject, for this is primarily addressed to those who have watched plant behavior less closely. We begin with the thesis that plants always behave, that is, they react, to sunshine and darkness, to drought and rain, to the food substances that may be supplied by way of the soil, and in far more diverse ways they react to the germs and other agents of disease that beset them on every hand.

The amateur flower lover, who watches every plant and bloom, knows the significance of blight and mildew, and the commercial grower of grain or fruit must nowadays be something of a specialist in rusts and leaf spots. And why? It is because the sum of the losses throughout the country, from such maladies, reaches a staggering figure, perhaps nearly a billion dollars annually, to say nothing of the agony of spirit which is the only loss registered by the amateur. There have been years when in the United States alone the grain rusts caused a loss estimated at $67,000,000. The potato blight has taken a toll of around $40,000,000 annually.

If there were for plants as a whole so few diseases as there are for human beings it would be a far simpler matter to learn about them, but practically every cultivated plant has its own particular round of diseases—its measles, diphtheria, scarlet fever and smallpox, we might say; but actually we have very distinctive names based upon the behavior of the plant affected. For example, there is the mildew of rose, the leaf curl and the brown rot of peaches, the blight of apples and pears, the tip burn of potato, the crown gall of grape, the witches broom of cherry, the white leaf spot of violets, the black knot of plum, the mosaic of tobacco, the smut of corn, and literally thousands of others too numerous to distinguish by popular terms alone.

Now these terms—rot, spot and what not—indicate how the plant is behaving, and always there is loss of production of flowers or fruits or whatever may be the harvest. When the peach leaves "curl," they later fall and there is no crop. When the rose shoots mildew, the

blossoms are imperfect. Even if the damage is relatively slight, who wants to buy scabby apples or blighted tulips?

Not only are the effects of plant disease so diverse, but the progress of disease in any particular case may be very rapid or very slow. Down through the Shenandoah Valley recently there was celebrated a great apple flower fête. In all that region the bees are busy gathering honey and incidentally pollinating those flowers. But if the fruit growers were not diligent, and if there were here and there in the orchards blighted trees of pear or apple which might be visited by the bees, the germs of blight would be spread far and wide. In a few weeks the dreaded fire blight would, as it were, sweep through the orchards, with a loss almost as great as from frost. This is an example of quick effect.

On the other hand, out there in the woods is a beech tree with a wind-broken stub of a branch. The stub dies and the fine mould like strands of a fungus grow into the wood of the stub, later into the living tree and gradually year after year the wood within decays. There comes a storm, and such a tree has lost its resistance; it falls easily before the wind. Then, if not before, we discover the cause, and see that the insidious agent of disease is as slow and yet as sure as cancer.

When I spoke a moment ago of the blight of apple and pear, we were dealing with a disease caused by a germ in the truest sense of the word. The organism causing this disease belongs to the same family of little germs as that causing tuberculosis of man, the bacteria. It is one of a great number of plant diseases due to different species of bacteria, and bacteria, you know, are very simple in form and microscopic in size.

The majority of plant diseases are caused by organisms that bear the name fungi, but not all fungi are disease producers. There are a few fungi familiar in the home, such as the bread or cheese moulds. From the standpoint of the complexity of living things these fungi are a little more respectable than bacteria. In many cases we can see the growth readily, even the vegetative growth, and in general this vegetative stage is in reality a vast entanglement of little threads. The disseminating bodies are minute spores.

Perhaps we can best illustrate these causes of disease by considering another case, and since the apple has been under discussion I will take the *apple rust* as an example—and, I must admit, a very curious example. The disease is almost uncanny in its behavior. At this season of the year it is not to be found on the apple at all but on the cedar instead.

If you go out into the woods now where cedars and crab apples abound, you will find on the little branches of the cedars certain galls as large as walnuts—cedar apples they are called. After a rain, a little later in the season, these galls will exude great orange-colored horns, bearing millions of spores that will spread this disease to apples, as we shall see in the orchards about. In other words, these cedar apples are just a peculiar growth of the cedar twig when infested with and permeated by this fungus. The spores from these cedar apples fall upon the young apple leaves, and there they grow into the living tissues. When summer comes, such affected leaves will show conspicuous orange spots, indicating a vigorous development of the fungus within. Both leaves and fruit may be affected and the damage in premature leaf drop and in fruit injury may be great. But before the leaves fall another type of spore is produced, and this must be carried by wind or rain back to the cedar, where another infection and growth of galls will occur. It is clear that when we know the life histories of these diseases—

or whence they come and where they go, and the time of it all—we shall know how and when to strike with preventive or remedial agents.

So far we have been speaking of bacterial and fungus diseases. We might almost say that we have tamed most of those. But there is another class of diseases phenomenal in every way. These are the so-called mosaic diseases. They are generally highly contagious, and any one can pick out the diseased plants yards away by the yellow and green, blotched appearance. The plants do not die, but they do not produce efficiently. There are such diseases of tobacco, tomato and potato, sugar cane and corn, bean and cucumber, columbine and Poinsettia. The potato with such a disease is often said to be running out or deteriorating, tomatoes produce only during the first part of the season, and the columbine fails to flower.

The remarkable thing is that the causes of these diseases are agencies so small or so peculiar that in no case have they been recognized with certainty under the microscope. We think it is beyond the power of the microscope to recognize them, that is, they are ultramicroscopic. This seems to place such causes of disease among what have been called virus diseases, of which there are several conspicuous examples among man and higher animals, such as smallpox, measles, rabies and others.

In the case of the mosaic of tobacco, for example, we know that the virus is transferable by insects which feed on the plant juices by pricking tiny holes in the leaves or stems. We know about the behavior of such a virus outside of the plant, because we can extract the juices of infected plants and then inoculate them into healthy plants and thus determine whether the virus is still active or not. But there is a solemn mystery about the thing, just as there is about force, about electricity. Imagine working with a disease germ that you are not able to visualize or perceive in any way except by seeing the behavior of a plant that is inoculated with it. We think that if we can solve the riddle of such virus diseases of plants we may be able to cast a flood of light upon the virus diseases of the human being.

Of course, we could eradicate apple rust in any region by destroying the cedar or eliminating the cedar galls. We control quite satisfactorily, by spraying, the more widely distributed diseases of the grape, of the apple, of the potato and of many other staple crops, and there has sprung up around this system of control an enormous industry in fungicides and fungicide machinery. We can not readily and practically control by spray methods the rusts of grain, peach yellows, the wilt of cotton, the various mosaic diseases and hosts of others. Look back a few years when our eastern woods were stocked with chestnuts. These are all gone or going, and a single disease, the chestnut blight, is the cause. Gradually, however, through the development of the research work that is being conducted in plant breeding and genetics we are realizing that varieties resistant to diseases may be found or may be produced in a large number of cases and that our ultimate conquest of such diseases must be through the propagation of resistant plants. In all the great domain of plant diseases there is no single case of immunity in the sense that a plant once diseased will become immune to further attacks of the same disease. The problem of acquired immunity so well defined in man and animals is then unknown in the plant kingdom. We may expect, therefore, that the same tree or bush or plant will be affected year after year if the disease germs reach it and if the weather conditions are favorable for the development of the malady.

Few persons outside of those actually in contact with the work realize, I dare say, the extent of the organization now in existence, functioning, as far as possible, to get new light on plant disease and to keep disease away from crops. In the U. S. Department of Agriculture, in the various state agricultural colleges and experiment stations and in many endowed educational institutions throughout the country, there are considerably more than a thousand trained scientific men devoting their time and energies to this work. That, remember, is merely the scientific side of it.

Fifty years ago there was in this country but a single student of plant diseases, Farlow, at Cambridge. A few years later Burrill, at the University of Illinois, recognized and described the first bacterial disease of plants. Shortly thereafter the Department of Agriculture and several other experiment stations entered the field, and now the organization for plant disease study in the United States is first in the world.

Perhaps it is true that the prevalence of fungus diseases in the United States has been the animating factor in our superb organization for research. We should bear in mind, however, that with all our present knowledge of plant diseases the problem of control will always remain, just as with human diseases. Some few diseases may be eradicated, and the vast majority may be satisfactorily—though often at considerable cost—controlled, but still others have baffled the best-laid plans of the pathologist.

THE PECULIARITIES OF THE SENSATION OF COLD

By Professor D. FRASER HARRIS

EAST GRINSTEAD, SUSSEX, ENGLAND

It may seem a curious thing to say that, although there is no such thing as cold in the sense that there is heat, yet we have in the body nerves for the sensation of cold. Let us try to make this mystery plain.

According to the present views of physicists, cold has no objective or "real" existence: whereas there *is* such a thing as heat and we can measure it. There are, moreover, nerves for the perception of heat.

Although there is no objective cold, there are nerves for perceiving cold.

Heat can be made to enter or leave a body; but as there is no such thing as cold apart from sensations, cold can not enter or leave a body.

Just as there is light and a nerve of vision wherewith to see light, so there is heat and there are nerves for the sensation of heat; but since there is no objective, external cold, it is remarkable that there should be nerves for the purpose of perceiving cold.

Heat is a more or less violent disturbance of the molecules of matter—gas, liquid or solid—and it can be transferred from one mass of matter to another. A change of temperature is the sign that heat is being transferred from the hotter to the colder body.

When two bodies are at the same temperature, there is no transference of heat between them.

Temperature is to heat what a head of pressure is to water in movement.

If we plunge a hot poker into cold water, the poker will lose heat and fall in temperature, the water will gain heat and rise in temperature.

The human body can absorb heat from the sun, fires, hot baths, etc., and we have the sensation of warmth in consequence: here heat is coming into the body. But the body is always producing heat, and heat therefore is always leaving the body; for if it did not, but accumulated continuously, the heat would in a few days cremate the living body.

If there is plenty of warm blood in the skin we feel warm as when we flush or blush; although heat is *leaving* the body; and conversely, when there is little blood in the skin, as in blanching and an ague-fit, we feel cold.

Some heat is leaving the body all the time; and yet we are not cold all the time: so long as there is a moderate amount of blood in the skin we feel comfortable and neither too hot nor too cold.

When under any circumstances the animal heat is carried off very rapidly, as into air when we rush through it in a motor car or to water as in a cold bath or to a solid when we sit on a cold stone seat, then we say, "it" is cold, we "feel" cold, we "are" cold, although there is no real cold in the outer world.

It is, therefore, not only the loss of heat but the rate of that loss which determines how cold we feel.

Thus when we place our hands in ice-cold water, we say it is much colder than ordinary drinking water only because in the former case heat is leaving the skin at a much faster rate than in the latter. It is a question of the *rate* of the transference of heat through the skin, and of the amount of blood in the skin at the time; for when there is plenty of blood

in the skin, as in blushing, we say we feel warm, although heat is leaving the body; but when there is not much blood in the skin and heat is still leaving it as in ague, we say we feel cold.

In any case, when we feel cold there is no such thing as external cold coming into our bodies from outside; on this both physicists and physiologists are agreed.

Let us consider one more case; suppose we close our eyes, and place the hand in oil at exactly the temperature of the body, we shall feel the hand neither hot nor cold, and we may not be aware of the presence of the oil at all. It must be quite a familiar experience that if we happen to cut a finger painlessly and without noticing the flow of blood, we do not feel the blood at all, and only know we have cut our finger by happening to see the blood somewhere. Blood at exactly the temperature of the body is not felt; as regards the body it is neither hot nor cold, and this state of physiological Laodiceanism is not perceptible. We seem, then, to be able to distinguish four cases:

(1) When heat comes in through the skin, we feel hot;

(2) When heat goes out through the skin, we sometimes feel cold;

(3) When heat goes out through the skin, at other times we feel hot. And (4) when heat neither comes in nor goes out, we have no thermal sensations at all.

Our sensations of heat or cold (thermesthesia) would seem to depend on the transference of heat and not on its direction across the skin.

The amount of blood in the skin is a powerful factor determining our sensations as to cold and therefore our opinion as regards the comfort, for instance, of a room. Thus, suppose a person has been sitting in a room without a fire doing hard mental work or having an ague-fit, he will be "cold all over"; even if his head is warm, his feet are cold; he is quite uncomfortable and says the room is cold and needs a fire. Just as he is about to light it, some one may come in from a brisk walk all aglow with plenty of blood in the skin who will at once pronounce the room quite warm and not in the least in need of a fire: it is a question of relativity. But the temperature of the room is exactly the same for both men.

The presence of blood in the skin will make a person feel warm, for a time at least, whatever be the thermal state of his environment, even although heat is continuously leaving the body.

Let us now carry out a very simple experiment: suppose we place in a basin of water at room temperature one finger previously chilled by ice-water, and another previously warmed by hot; then the water will appear hot to the cold finger and cold to the warm finger. Yet of course the water can only be all of one temperature: the sensations are called contrast effects; but they are another case of relativity. Evidently the state of adjustment on the part of the nerves of the skin towards the passage of heat across them must be a factor determining whether we feel hot or cold.

That state of the skin in which we feel an object neither hot nor cold is called its "adaptation temperature" or its "physiological zero."

We can be still more explicit and say the physiological zero is of such a kind that if the temperature of the environment rises above it the sensation is of heat, but if below it, the sensation is of cold.

Lastly, do we possess nerves for perceiving cold as distinct from those for heat? It is believed we do. The whole of the evidence can not be given here; but some of it may be learned from a careful exploration of the skin carried out by a simple instrument.

The instrument is merely a rod of metal, *e.g.*, copper (about the diameter of a lead pencil), cut to a not too fine point. If this rod be repeatedly pressed

lightly on the skin, point by point, and the blindfolded person asked to report his sensation at each time of contact, then the possible reports are: "touched"; "hot"; "cold"; "doubtful"; "nothing."

By "doubtful," the person means he is not quite sure whether the spot touched feels hot or cold or has merely had a contact: by "nothing" he means that although he *knows* he is being touched by the rod, the sensation is neither hot nor cold but is so vague that he is not positive about the contact. As a matter of fact, the rod is over a pain-spot, but the pain will not be elicited until the pressure becomes greater. Hitherto the rod is supposed to be at room temperature. If now we chill the rod in ice-cold water and apply it as before, the reports are—"contact"; "distinctly cold." In this case the moment a "cold spot" is touched, the sensation is very obviously cold; but the heat-nerves are not stimulated. If the rod be at the temperature of the skin, then only contacts are reported. If an area of skin be selected, say, on the back of the hand and the contact, the hot and the cold spots are marked out each with a different color, then it can be seen that the pattern for each nerve is different from the others.

There are more cold spots than hot spots per unit area of skin.

As regards internal organs, their endowment for perceiving heat and cold is very imperfect: we can swallow liquids painfully hot or cold to the lips and scarcely perceive them when once they have reached the stomach.

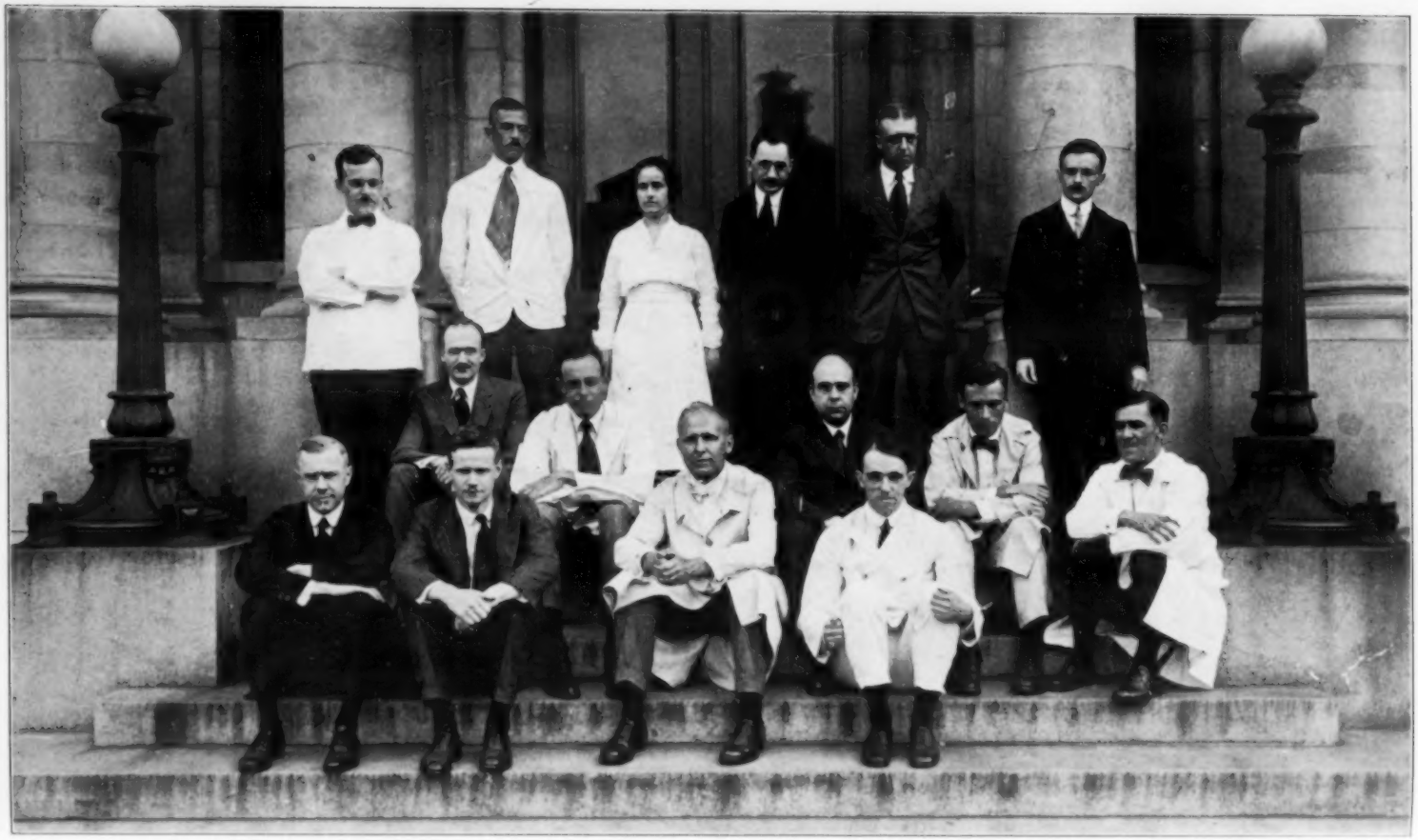
The general inference from all this is that the peripheral endings of the nerves for the sensation of cold are distributed in the skin in a punctate manner; and that they are stimulated moderately by a rod at room temperature and much more vigorously by one thoroughly chilled.

Further we may infer that the distribution of the cold-perceiving nerves is different from that of the hot nerves and also from the contact nerves. We have evidence that the impulses coming in on the hot and cold nerves travel up in a part of the spinal cord which is distinct from those tracts in which impulses of touch and of the muscular sense travel. Thus it is that a person who has sustained a particular kind of injury to the spinal cord has no sensations of heat or cold or pain so that he can pick up a red-hot coal or an excessively cold piece of metal and feel no pain.

The cold-perceiving nerves can be stimulated chemically, as, for instance, by menthol. If you rub some pure menthol on the skin of the forehead, then for some time afterwards everything will seem very cold. Touching the skin with a finger, even blowing over it, far less placing a bit of ice on it, will all be interpreted as very cold.

Thus we have learned that although there is no such thing in the universe as objective ("real") cold in the sense that there is heat, yet we have a system of nerves in the body with endings in the skin whose office it is to perceive cold as distinct from heat.

The more we know of how our bodies are constructed and endowed, the more we must wonder at the details of their capabilities and adaptations, even although we do not always fully apprehend their meaning.



DR. JOHN HOWLAND

PROFESSOR OF PEDIATRICS IN THE JOHNS HOPKINS UNIVERSITY, WHOSE RECENT DEATH IN LONDON IS A SERIOUS LOSS TO MEDICINE AND TO SCIENCE. THE PHOTOGRAPH, WHICH WAS TAKEN IN 1920, SHOWS PROFESSOR HOWLAND WITH HIS STAFF IN THE JOHNS HOPKINS HOSPITAL.

THE PROGRESS OF SCIENCE

By Dr. Edwin E. Slosson
Director of Science Service, Washington

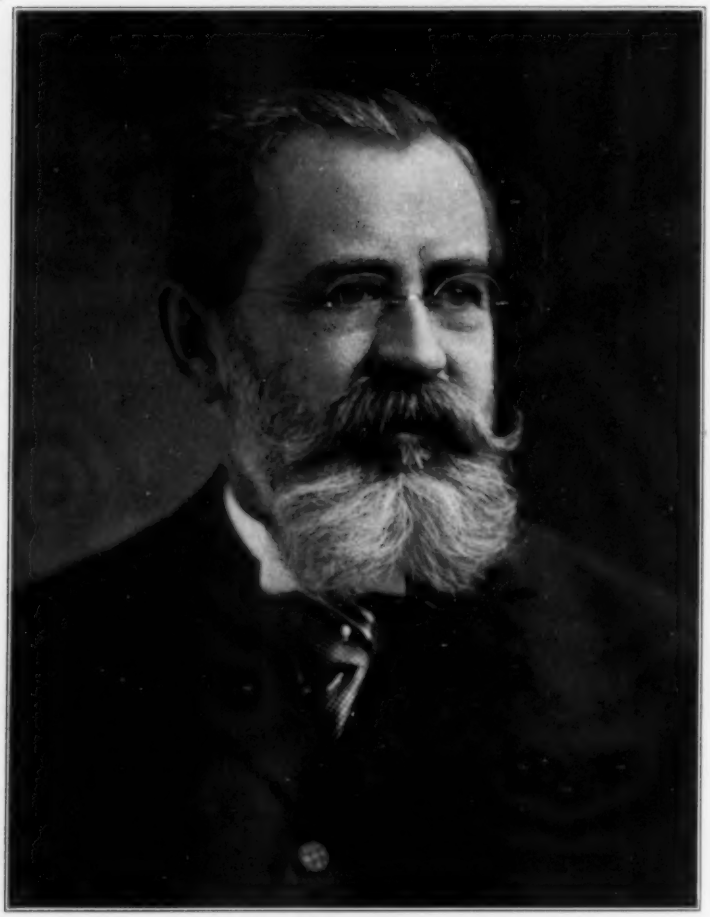
ELECTRIC FARMING

One of the funniest things I saw in Sweden when I was over there recently was the use of electrical cookstoves in forest cottages. Sweden is short on coal and oil, but long on wood and water. The Swedes are growing trees faster than they are cutting them, the reverse of the policy that prevails in America. Consequently they have wood to burn, but they prefer to cook with water instead. The water falls down faster than the trees can grow up. So they turn it into turbines and with them grind the wood into pulp, and ship it over to America to be made into the yellow journals and silky stockings that are so conspicuous in our country. Electricity is cheap over there and besides they have an ingenious kind of cooking contrivance that keeps in the heat and the steam, so a few watts will cook a lot of food, and it takes a lot of food to satisfy a Swede.

About forty-five per cent. of the farms of Sweden are using electricity for lighting and light power. In the United States "not more than three per cent. of the farms are receiving electric current from power lines," according to G. E. Tripp, chairman of the Westinghouse. California, of course, claims the lead, with 554,000,000 horse-power-hours of electric power used in agriculture during the year 1923, but eighty per cent. of that is employed in pumping water for irrigation. The number of electric power consumers on farms in California is reported as 26,915. Ohio has 17,000 farms supplied with rural electric service and Iowa and Pennsylvania have about 12,000 each.

To read over the list of the applications of the current one would think that the electrical farmer hadn't any chores to do and that the electrified stock were living in the lap of luxury. I am skeptical, as one of my age naturally would be, about the moral effect of all these new-fangled ways. Incandescent lights in the pigpen! Electric fans in the cattle shed! Ultraviolet rays for hogs and hay! Is it good for young hens to be kept up all hours of the night under the white lights, gadding about and stuffing their crops with rich food? Can a thermostat altogether replace the maternal instinct?

And what will be the effect on the farmer and his family? Will he continue his commendable habit of early rising if he can milk a dozen cows at a time by simply turning on the juice? Will not the farmer's wife lose the well-rounded arms that she developed by long hours at the churn and the rosy complexion that she acquired over the cook stove? Will the tungsten filament give that well-grounded education that we, or anyhow our forefathers, got by means of the torch or tallow dip? Will the tennis racket adequately take the place of the buck-saw in the development of the muscles and the sense of duty? In short, will those whose hardest labor has been to press a button or jerk a switch acquire those sterling qualities which have made us what we are?



DR. CARL HERING

IN WHOSE DEATH PHILADELPHIA AND THE COUNTRY LOSE ONE OF THEIR MOST DISTINGUISHED ENGINEERS

A QUEER KETTLE

"IF a kettle of water be placed on a fire there is a chance, though an exceedingly small one, that the water will freeze." This startling saying, quoted from Planck by Paul R. Heyl, of the Bureau of Standards, is an admirable illustration of how much the scientific viewpoint of the twentieth century differs from that of the nineteenth.

We were taught in school that heat always flows from a hot to a cold body, and we verified this law for ourselves frequently and sometimes unpleasantly. If we touched a boiling tea-kettle, the heat flowed into our finger before we could snatch it away. If we touched a lump of ice the heat ran into the ice and the finger became cold.

Twentieth-century physicists do not presume to contradict these facts, nor do they propose to abrogate the law, yet they point out that the law is not an ab-

JEAN PAINLEVÉ

SON OF THE DISTINGUISHED MATHEMATICIAN AND FORMER FRENCH PREMIER, WHO HAS HIMSELF WON REPUTATION IN SCIENTIFIC RESEARCH, APPEARING IN A FILM CALLED "L'INCONNU DES SIX JOURS," THE PROCEEDS OF WHICH WILL BE TURNED OVER TO LABORATORIES IN WHICH HE IS INTERESTED. WITH HIM IS MIRKO, A RUSSIAN WOLFHOUND, WELL KNOWN IN FRENCH CINEMA CIRCLES.

solute rule but a statistical average, based upon the calculation of probabilities. It holds in the long run and on the whole, yet there may be, in fact must be, local and temporal exceptions.

Just so a man might say of the Hudson River tunnel that in the morning the crowd flows from New Jersey to New York, and in the evening from New York to New Jersey. Quite true, yet if we look more closely we observe that a minor proportion of passengers are going in the opposite direction from the majority, both morning and evening.

Now from the point of view of the physicist the difference between a hot body and a cold body is that in the former the molecules are moving about more rapidly *on the average*. But the molecules of both are moving with various and varying velocities, and when the two bodies are in contact they influence one another, both ways. Heat *is* continuously flowing from the cooler to the warmer, running up hill, so to speak, but this minor effect is masked by the overwhelming current of heat running down to the cooler body.

Nevertheless, as Dr. Heyl points out, this involves the admission that perpetual motion, which was anathema to nineteenth century science, is theoretically possible on a very small scale, although it is practically impossible on a large scale. In other words, the heat *might* all run from the kettle of water to the fire—only it never does.

DR. WILLIAM CROCKER

DIRECTOR OF THE BOYCE INSTITUTE OF PLANT RESEARCH, A DESCRIPTION OF THE IMPORTANT WORK OF WHICH BY PROFESSOR JOHN M. COULTER APPEARS IN THE PRESENT ISSUE OF THE MONTHLY.

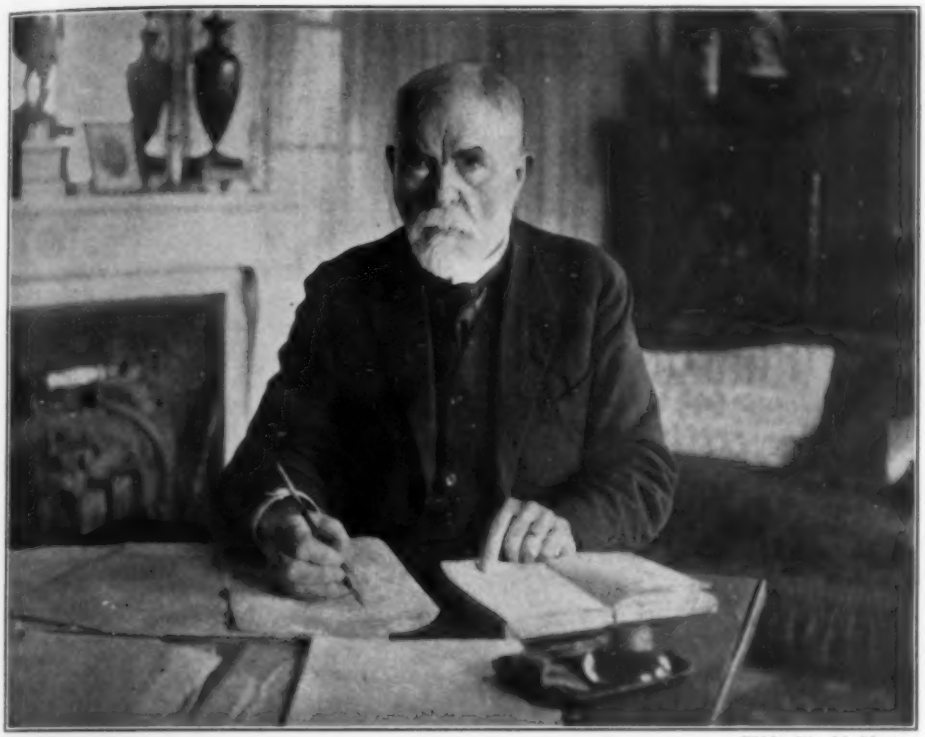
PROFESSOR LUCIEN GALLOIS

BY PROFESSOR DOUGLAS JOHNSON

Columbia University

IN conferring upon Lucien Gallois its Cullom Medal the American Geographical Society has most appropriately honored the distinguished dean of French geographers. Those who know the man and his work will agree that the distinction could hardly have been more worthily bestowed.

Lucien Gallois, who will soon attain the Biblical age of threescore years and ten, looks back upon a long and honorable service in the chairs of geography in the University of Lyons, in the École Normale Supérieure, where he succeeded the founder of the modern French school of geography, Vidal de la Blache, and in the Sorbonne, where he continues to exert a profound influence upon geographical work in France. Here not only do future teachers and investigators of geography benefit by his vigorous analyses and criticisms of their work in a seminar which it is a real privilege to attend; but in public courses of lectures large numbers of laymen hear from his lips masterly expositions of the geographical

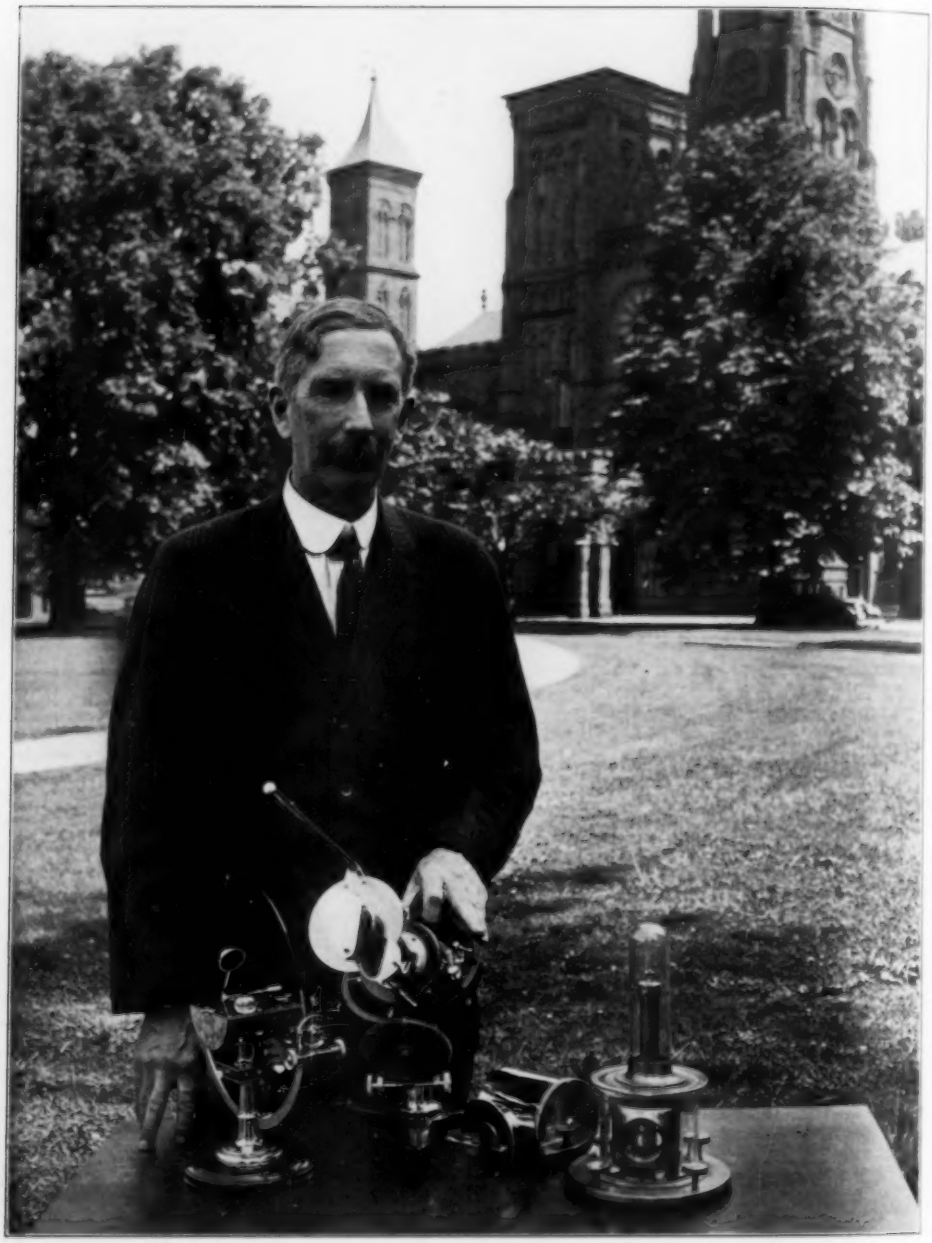


Wide World Photos

PROFESSOR LUCIEN GALLOIS

features of their country. One who is so favored as to have him for a guide through the byways of old Paris will profit richly from his inexhaustible knowledge relating to the geographical development of the city; for Gallois is a specialist in urban geography, and Paris is the object of some of his monographic studies.

Outside the university Gallois' influence is felt in many fields. Students of geography the world over know him as one of the leading spirits in creating and maintaining the high character of the *Annales de Géographie*, one of the few really indispensable geographical periodicals published at the present time. Prior to the Paris Peace Conference he served on the French Comité d'Études, a semi-official body created to study problems of the peace which in organization and in methods resembled the "Inquiry" formed in America for the same purpose under the direction of Colonel House. To the publications of this Comité Gallois contributed studies of the Sarre Basin, of the northeastern frontiers of France, of the Rhine River, of the port of Salonika and of other regions politically important. More widely known are his volume on "Régions Naturelles et Noms de Pays: Étude sur la Région Parisienne," and his other writings on Paris and the surrounding country, as well as his contributions to our knowledge of the history of geography in Europe. In France his preeminent position has been fittingly recognized by his election as president of the Association de Géographes Français, while in America many will remember him as an honored guest on the American Geographical Society's Transcontinental Excursion of 1912.



DR. CHARLES G. ABBOT

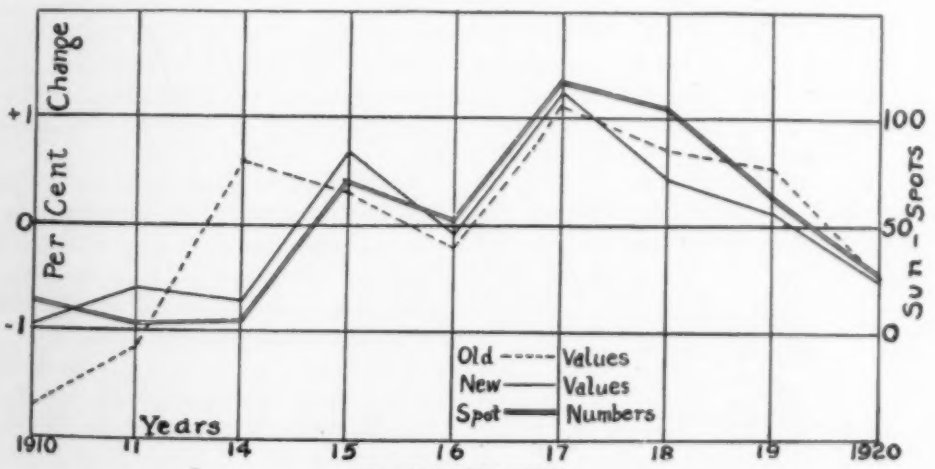
ASSISTANT SECRETARY OF THE SMITHSONIAN INSTITUTION AND DIRECTOR OF THE ASTROPHYSICAL OBSERVATORY, WHO HAS RETURNED FROM AN EXTENSIVE TRIP ON BEHALF OF THE NATIONAL GEOGRAPHIC SOCIETY'S SOLAR RADIATION EXPEDITION.

It is a double pleasure when well-deserved honor is conferred upon one whose high erudition is graced by the charms of a delightful personality; for then both the head and the heart rejoice. This double pleasure was experienced by the friends of Lucien Gallois on learning that he had been awarded the Cullom Medal. Both in his writings and in personal contact he reveals a simple directness of method, a sincerity of thought and a modesty of manner which can not fail to impress all fortunate enough to know him. Those who go to him for help find something more; a man with a big heart, ready to give generously of his time whenever and wherever his rich store of knowledge can be made to serve the cause of geographic science.

VARIATION OF THE SUN'S HEAT

A DEVELOPMENT which bids fair to rank high in weather forecasting is announced in the latest issue of the *Monthly Weather Review* of the U. S. Weather Bureau, by Dr. Charles G. Abbot, of the Smithsonian Institution. That development is the discovery of a new and simple proof by Dr. Abbot that the amount of heat given off by the sun from day to day and from year to year varies. If the proof is final—and it seems irrefutable—there can be no further question that the sun is a real factor in the daily and yearly weather changes. Exact appraisal of its value for long-range weather forecasting awaits only the further perfection of measurements of solar variation and world weather. At all events, an essential element new to weather forecasting has been discovered and proved. Its application is only a matter of research and time.

For thirty years Dr. Abbot has been investigating the sun and measuring the heat it sends to the earth. In 1903 he surmised from his results for previous years that the amount of that heat varied. Urged on by that clue and its



SOLAR VARIATION

THIS GRAPH, DRAWN BY DR. ABBOT, SHOWS THAT THE SUN VARIES. THE DOTTED LINE SHOWS THE CHANGES FOR JULYS 1910–1920 ACCORDING TO THE SOLAR CONSTANT VALUES ALREADY PUBLISHED BY THE SMITHSONIAN. THE BLACK LINE SHOWS THE VARIATION NEWLY DETERMINED FROM MEASUREMENTS MADE ON DAYS WHEN ATMOSPHERIC CONDITIONS WERE IDENTICAL. THE DOUBLE LINE SHOWS VARIATION OF NUMBER OF SUNSPOTS OBSERVED DURING THESE JULYS BY EUROPEAN ASTRONOMERS.

great significance to mankind if true, he has spent the intervening years in elaborate measurements of solar radiation in many parts of the world: at Mount Wilson and Mount Whitney, California; at Bassour, Algeria; at Mt. Harqua Hala, Arizona, and Mt. Montezuma in the nitrate desert of Chile. He developed instruments capable of measuring a millionth of a degree change in temperature, and other instruments of the greatest complexity and usefulness to be used in connection with his measuring instruments for standardizing and for computing results.

The proof which Dr. Abbot now announces appears to finally refute all criticisms and leave no further doubt of the variability of solar radiation. The essence of this proof lies in a comparison of measurements of solar radiation made at times when the atmosphere is practically identically the same. It is obvious that if the atmosphere is the same and the instruments are correct any changes must mean differences in the amount of heat given off by the sun.

Dr. Abbot selected measurements made in the month of July for the years 1910 to 1920, omitting the years 1912 and 1913 because the volcano of Mt. Katmai in Alaska filled the atmosphere of the whole northern hemisphere with dust in those years. During all these years Dr. Abbot and his assistant, Mr. L. B. Aldrich, has measured the sun from the same observatory on Mt. Wilson, California. They used the same instruments throughout and these instruments were regularly tested against standards and found unchanged.

From the measurements made in these months, he selected the days when the atmospheric transparency and its content of water vapor were practically the same, dividing these into comparable groups. All days in any year in which atmospheric conditions were not practically identical with those in other years he discarded.

He then plotted the measurements of the total quantity of heat received at the earth's surface. On the same paper he plotted the solar constant values for these years as previously published. These solar constant values are the result of the measurements of the total quantity of heat received at the earth's surface, corrected by measurements of the loss of heat through the earth's atmosphere so as to indicate what would be found outside it—on the moon, for instance. How closely the two results parallel one another is shown by the accompanying chart.

As a further proof of the accuracy of his measurements of the variability of solar radiation, Dr. Abbot plotted the average number of sun spots for Julys of the same years on the same paper. The harmony is again apparent.

Such is a simplified account of the proof that the radiation from the sun varies over a long period of time closely in harmony with the sun's visible evidences of activity. Dr. Abbot did not stop here, but used a slight modification of the same method to show that short interval changes within the individual months are also verified by this simple process.

With this great step accomplished, the next move is to make the daily measurements of solar radiation as accurate as is humanly possible. To help to accomplish this, the National Geographic Society has given $55,000 to establish a solar observatory at Mt. Brukkaros in Southwest Africa to cooperate with Dr. Abbot's two existing stations in California and Chile. To insure that at least one accurate measurement be made for every day in the year, a fourth station is needed in the northern section of the Eastern Hemisphere.